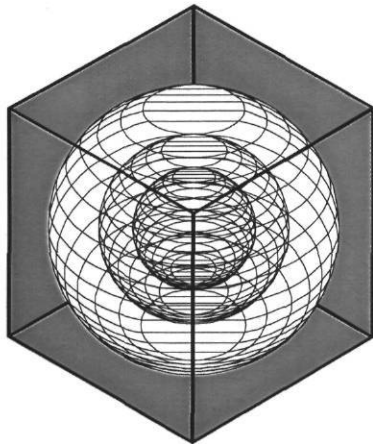


# **TEXAS' SENATE BILL 5 LEGISLATION FOR REDUCING POLLUTION IN NON- ATTAINMENT AND AFFECTED AREAS:**

## **Annual Report to the Texas Natural Resource Conservation Commission**

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## **ENERGY SYSTEMS LABORATORY**

Texas Engineering Experiment Station  
Texas A&M University System

## 1 EXECUTIVE SUMMARY

This is the first annual report by the Energy Systems Laboratory, which covers the Laboratory's efforts to support Senate Bill 5. In this report the accomplishments and progress to date are presented, along with recommendations, issues encountered to date and what is needed to fulfill the Laboratory's responsibilities. A section of this report also discusses the technology of reporting and verifying emissions reductions from the energy used in buildings, and presents an overview of the technologies for reducing energy use in buildings. Preliminary findings are also presented regarding the estimation of NOx reduction from several building-related energy conservation measures, and recommendations are provided regarding improvements to the NOx accounting methods.

### 1.1 Accomplishments/Budget

#### 1.1.1 Budget

In the General Appropriations Act, the Texas Engineering Experiment Station was appropriated \$1,363,060 for FY2002 and \$1,293,060 for FY 2003 out of the Texas Emission Reduction Plan Fund to perform the Laboratory's responsibilities under SB5. In December of 2001, the Comptroller announced that problems in collections existed and that only approximately \$58 million of the planned \$276 million would be collected over the first biennium. The Laboratory's budget was then projected to be reduced to approximately \$250,000 per year for the first two years. The Laboratory has currently received \$158,859 through August of 2002.

#### 1.1.2 Progress Since September 2001

Since September 2001, the Energy Systems Laboratory has been able to accomplish the following:

- o Estimated NOx reductions from implementation of the IECC/IRC to new residential construction, and other measures.
- o Created IECC/IRC code-traceable simulation test suite
- o Provided IECC/IRC Training Sessions
- o Laboratory's Senate Bill 5 Web Site operational
- o Builder's Guide (Version 003) published
- o Self-Certification Form (Version 1.3) published
- o Created several Senate Bill 5 Stakeholders Group
- o Resolved the R-6 versus R-8 Flexible Duct Issue
- o Implementation Date support provided to Senator Brown
- o Responded to about 40 to 60 calls per week
- o Submitted code amendment review for NCTCOG
- o Requested by NCTCOG and City of Houston to approve Energy Star as alternative compliance path to the IECC/IRC, including approval REMRate and EnergyGauge USA as above alternative paths.
- o Delivered Senate Bill 5 Sessions at Hot and Humid Conference
- o Delivered 'Building Energy Codes and Technologies' at the TCET Symposium for Reducing Emissions in Texas, May 21, 2002, Houston, Texas
- o Development of an analysis plan to report energy reductions and link to emissions reductions
- o Requested to allow R6/SEER 12 tradeoff.
- o Developed HERs Standardized input form.

This report discusses each of these accomplishments, and how they are relevant to Senate Bill 5.

### 1.2 Estimated NOx Reductions

In this report estimates of NOx reduction potential have been provided for several buildings-related measures, including:



- Implementation of the IECC/IRC to new residential single family construction,
- Restarting the LoanSTAR and Rebuild America M&V program, combined with Continuous Commissioning<sup>SM</sup>.
- Motivating consumers to purchase SEER 12 air conditioners.
- Increased use of efficient refrigerators.
- Increased use of efficient clothes washers.
- Increased use of Low-E windows.
- Increased use of solar thermal DHW systems.
- Increased use of compact fluorescents.
- Elimination of pilot lights.

The following estimates are included for Legislative planning purposes to provide decision-makers with estimated NOx reduction potentials from several different alternatives, which are detailed in the report.

ITEM	Cost to Implement (\$ Million)	Energy Savings (GWh/yr)	Tons-NOx/yr	Tons-NOx/day	\$/ton-NOx-10yr	\$/ton-NOx-10yr-day
IECC/IRC	\$45	297	334 – 500	1.7 – 2.5	\$9.1k – 13.7k	\$14 – \$21
LoanSTAR M&V	\$5.2	73 – 122	46 – 78	0.2 – 0.3	\$9.7k – 16.2k	\$27 – \$89
SEER 12 avg	\$85 – 213	248 – 537	191 – 414	0.5 – 1.1	\$20.6k – \$111.6k	\$56-\$306
SEER 12 peak	\$85 – 213	248 – 537	191 – 414	1.6 – 3.6	\$20.6k – \$111.6k	\$56-\$306
Refrigerators	\$662	728 – 1,092	617 – 926	1.7 – 2.5	\$71.5k – \$107.3k	\$196 – \$294
C. Washer	\$2,384 – 5,563	2,622 – 3,496	2,221 – 2,962	6 – 8	\$107.3k – \$187.8k	\$294 – \$515
Eff. Lighting	\$573-\$662	6,381 – 7,799	4,914 – 6,006	13.5 – 16.5	\$52.5k – \$55.6k	\$152 – \$144
Low-E Win.	\$3,178 – 3,973	22,794 – 28,493	17,552 – 21,940	96 – 121	\$18.1k	\$99
Solar DHW	\$13,245 – \$21,193	8,534 – 21,849*	3,640 – 9,319	10 – 26	\$227.4k – \$363.9k	\$623-\$997
Pilot Lights	\$750 – \$1,788	9,635 – 15,303*	4,109 – 6,527	11 – 18	\$18.3 – \$27.4k	\$50 – \$75

NOTE: \* GWh Savings are calculated from MMBtu thermal savings. Highlighted measures are viewed as the most attractive.

Table 1: Estimated NOx reduction potential for several building-related measures.

In Table 1 several features are worth pointing out. First, the potential for NOx reductions in building energy use is significant, varying from a few tons per day to hundreds of tons per day in the case of Low-E windows retrofitted to every residence. These measures have varying costs associated with them, which can best be judged by viewing either the \$/ton-NOx-10yr, or the \$/ton-NOx-10yr-day. For example, the measures with the greatest potential for reducing NOx emissions appear to be energy efficient lighting and Low-E windows. However, the measures that appear to be the most cost effective are the IECC/IRC and restarting the LoanSTAR monitoring and Continuous Commissioning<sup>SM</sup> program.

Second, two different calculations are provided for SEER 12 air conditioner upgrades to demonstrate the need to give careful consideration to the NOx accounting procedures. Currently, the EPA has encouraged the TNRCC to use the EGRID database of lbs-NOx/MWh values for power generation facilities. Unfortunately, this analysis procedure calculates the tons-NOx/day by dividing the annual tons-NOx by 365 to arrive at a daily average value of tons-NOx/day. As indicated in Table 1, this undercounts the potential NOx reduction from energy efficiency improvements such as air conditioners by 2:1. In the table the SEER 12 average day value shows the estimated NOx reductions from upgrading air conditioners to be 0.5 to 1.1 tons NOx/day and the SEER 12 peak tons NOx/day of 1.6 to 3.6 tons NOx/day. Therefore, it is recommended that the TNRCC consider modifying the use of the EGRID program to more accurately account for energy efficiency improvements that are undercounted by average-day calculations

Finally, these recommendations are provided so that the Senate Bill 5 policy makers will have preliminary NOx reductions estimates for a range of new policy areas that show potential for further study. Many of the values shown represent the maximum potential estimates for NOx reductions and would require substantial investments over a series of years. Therefore, detailed study is recommended for each of the measures listed before legislation is created.

### 1.3 Potential From Implementation of the IECC/IRC to New Residences

The Laboratory has estimated the NO<sub>x</sub> reduction potential from the Implementation of the 2000 IECC/IRC for new single-family residences, which are projected to be built in the non-attainment and affected counties. Results of this effort are presented in Section 7 of this report.

### 1.4 Energy Systems Laboratory's Responsibilities for Senate Bill 5.

Texas Senate Bill 5 has outlined the following responsibilities for the Energy Systems Laboratory:

- Section 386.205 - Evaluation Of State Energy Efficiency Programs.
- Sec. 388.003. Adoption Of Building Energy Efficiency Performance Standards.
- Sec. 388.004. Enforcement Of Energy Standards Outside Of Municipality.
- Sec. 388.007. Distribution Of Information And Technical Assistance.
- Sec. 388.008. Development Of Home Energy Ratings.

This report outlines the tasks that have been accomplished by the Laboratory since September 1<sup>st</sup>, 2001, and discusses recommendations, and problems encountered.

### 1.5 Recommendations

The Energy Systems Laboratory recommends the following to improve the effectiveness of Senate Bill 5:

- Work with the TNRCC, PUC and SECO to develop standardized methods for reporting NO<sub>x</sub> reductions, including adjustments to electricity savings needed for use of the EPA's EGRID program.
- Study methods to identify the maximum, cost-effective NO<sub>x</sub> emissions reductions from energy use in existing housing stock, and in existing commercial and industrial buildings.
- Capture and document the energy savings in Texas LoanSTAR and Rebuild America programs currently in place.
- Refinement of the analysis method for reporting emissions reductions, including eventual use of Ozone modeling programs such as CAMx.

### 1.6 Technology of Reporting and Verifying Emissions Reductions From Energy Used in Buildings

#### 1.6.1 Procedures for Calculating Electricity Reductions

Residential Buildings. The proposed methodology to accomplish this for residential buildings is composed of several procedures that will calculate and verify savings using several different sources of information. These procedures include:

- The calculation of electricity savings and peak demand reductions from the implementation of the IECC 2001 in new residences in non-attainment and affected counties as compared against 1999 housing characteristics (IECC 2001 residential emissions reductions) using calibrated simulation.
- A cross-check of the calculated energy use against the published average energy use found in the USDOE's Residential Energy Characteristics Survey (RECS 1999)
- A cross-check of electricity savings using a utility bill analysis method.
- A cross-check of construction data using on-site visits.

Commercial Buildings. The proposed methodology to accomplish this for commercial buildings is also composed of several procedures that will calculate and verify savings using several different sources of information. These procedures include:

- The calculation of electricity savings and peak demand reductions from the implementation of the IECC 2001 in commercial buildings in non-attainment and affected counties as compared against 1999 commercial building characteristics (IECC 2001 commercial emissions reductions) using calibrated simulation.
- A cross-check of the calculated energy use against the published average energy use found in the USDOE's Commercial Building Energy Characteristics Survey (CBECS 1995)
- A cross-check of electricity savings using a utility bill analysis method.

- A cross-check of construction data using on-site visits.

Renewables Applied to Buildings. The application of renewable energy systems in buildings are also addressed by the 2000 IECC/IRC. To account for the energy savings from these activities, procedures similar to new construction will be applied.

#### 1.6.2 Procedures for Calculating Ozone Reductions.

In this report two types of calculation procedures are discussed in this report in regards to the estimation of emissions reductions from buildings: data requirements for the calculation of annual NO<sub>x</sub> reductions, and data requirements for hourly ozone modeling. The first procedure requires annual, countywide kWh reductions and peak kW reductions. The second procedure requires data and calculations from several state agencies, university labs and private entities. The procedure begins with simulated, hourly, county-wide electricity savings from the implementation of the IECC/IRC to residential, commercial and industrial facilities, followed by the calculation of the electrical power production at the power plant using the appropriate grid model. The hourly, plant-specific power generation is then linked to hourly, TNRCC-measured pollutants for each plant to obtain the hourly, NO<sub>x</sub>, VOC and other pollutants associated with the power production at the time of the simulation. These hourly NO<sub>x</sub> and VOC are then merged together with other sources of NO<sub>x</sub> and VOC and fed into an hourly photochemical model along with the prevailing weather conditions to allow for the calculation of the ozone pollution (i.e., Ozone day or August-September 2000 Episode day) to determine the reduction in ozone. Although this description is overly-simplified, four groups must work closely together to accomplish this task. These are the Laboratory, TNRCC, ERCOT and the UT Atmospheric Sciences Group. This group can put a solid, defensible set of ozone reductions forward to the USEPA. Additional groups may need to be added to this core group to assure all building-related savings are accounted for in the modeling, including: SECO, PUC, SERC, SPP and WSCC. The legislature could address how to allow these data to be acquired as truly needed. Deregulation of the electric utilities is also complicating the acquisition of needed data.

#### 1.7 Technology of Reducing Energy Used in Buildings

Adoption of the 2000 IECC/IRC has allowed the state of Texas to define the minimum energy performance for new buildings and for existing buildings that are remodeled. In this report technologies are briefly reviewed that can have a substantial impact on delivering above-code building performance for residential, commercial and industrial buildings in Texas Buildings. In general for residential buildings, the 2000 IECC/IRC provides prescriptive measures for each climate zone in Chapters 5 and 6 to assure that new construction meets a minimum, predictable energy use. A residential performance path is provided in Chapter 4. Commercial buildings are addressed by minimum prescriptive measures in Chapter 8 of the 2000 IECC/IRC, or by minimum performance measures using ASHRAE Standard 90.1 1999, which is referenced by Chapter 7.

Technologies for reducing energy use in buildings are reviewed in this report, including the following technologies:

- Building Envelope.
- Appliances
- Heating/Cooling Systems
- Low NO<sub>x</sub> Technologies for Building Systems
- Industrial
- Other: Restaurants and Grocery Stores
- Renewables

## 1.8 Additional Opportunities

### 1.8.1 Industry

The key roadblock has been the lack of funding. This ripples through all activities and creates situations where the Laboratory has to focus only on emergencies. In general, the cooperation and enthusiasm of all parties (including the builders/builder groups, manufacturers, public interest groups and other agencies) has been very understanding and supportive. This lack of adequate funding has seriously slowed the Laboratory's progress in making the code adaptation a smooth process in Texas.

Cost and health impacts from the adoption of the codes have also arisen as a major issue. Cost impact needs to be studied and documented. Likewise, builders and homeowners are concerned about the health issues of tight buildings. The Laboratory needs to demonstrate and make these methods available to Texas builders.

### 1.8.2 Technology

The Laboratory has initiated meetings with ERCOT, and the CEER at the University of Texas to identify the technology needed to accurately measure, model and predict ozone reductions from implementation of Senate Bill 5. Additional meetings were held with TNRCC to better understand the current modeling methods. To accomplish the most accurate ozone modeling methods, four groups must work closely together. These are the Laboratory, TNRCC, ERCOT and the UT Atmospheric Sciences Group. This group can put a solid, defensible set of ozone reductions forward to the US EPA. Additional groups may need to be added to this core group to assure all savings are accounted for in the modeling, including: SECO, PUC, TxDOT, SERC, SPP and WSCC. The legislature could address how to allow these data to be acquired as truly needed. Deregulation of the electric utilities is also complicating the acquisition of needed data.

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## 2 INTRODUCTION

### 2.1 Background

Thirty-eight counties in Texas have been designated by the EPA as either non-attainment or affected areas. These areas are shown on the map in Figure 1, as non-attainment (dark-shaded), and affected (shaded). The sixteen counties designated as non-attainment counties include: Brazoria, Chambers, Collin, Dallas, Denton, El Paso, Fort Bend, Hardin, Harris, Jefferson, Galveston, Liberty, Montgomery, Orange, Tarrant, and Waller counties. The twenty-two counties designated as affected counties include: Bastrop, Bexar, Caldwell, Comal, Ellis, Gregg, Guadalupe, Harrison, Hays, Johnson, Kaufman, Nueces, Parker, Rockwall, Rusk, San Patricio, Smith, Travis, Upshur, Victoria, Williamson, and Wilson County.

These counties represent different areas of the state that have been categorized into the different climate zones by the 2001 IECC<sup>1</sup> as shown in Figure 2, namely, climate zone 5 or 6 (i.e., 2,000 to 2,999 HDD<sub>65</sub>) for the Dallas-Ft. Worth and El Paso areas, and climate zones 3 and 4 (i.e., 1,000 to 1,999 HDD<sub>65</sub>) for the Houston-Galveston-Beaumont-Port Author-Brazoria area. Also shown on Figure 2 are the locations of the various weather data sources, including the seventeen Typical Meteorological Year (TMY2) (NREL 1995), and four Weather Year for Energy Calculations (WYEC2) (Stoffel 1995) weather stations, as well as the forty-nine National Weather Service weather stations, (NWS) (NOAA 1993).

To no surprise, these thirty-eight counties represent some of the most populated counties in the state, and contained 13.9 million residents in 1999, which represents 69.5% of the state's 20.0 million total population (U.S. Census 1999). As shown in Figure 3, three of these counties (i.e., Harris, Dallas, and Tarrant), are non-attainment counties. The fourth county, Bexar county, is classified as an affected county. These four counties contain 8.0 million residents, or 40.0% of the state's total population. In the rankings of the remaining counties it is clear to see that the most populated counties also represent the majority of the non-attainment regions.

In Figure 4 the total housing units trends in the non-attainment and affected counties is shown to closely follow the county populations, with Harris, Dallas, Tarrant, and Bexar counties containing 3.2 million housing units, or 40.0% of the state's total 8.0 million households (U.S. Census 1999). However, in Figure 5 the 1999 residential building permit activity differs from the population and total housing unit trends, with the most activity occurred in Harris county (25,862 units), followed by significantly less construction in the five counties in the 10,000 to 15,000 unit range, including Dallas, Travis, Bexar, Collin and Tarrant counties. These six counties represented 88,833 housing starts, or 71% of the total 125,100 residential building permits in the 38 counties classified as non-attainment or affected by the EPA.

Also of interest in Figure 5 is the significant number of new multi-family units in the counties with the largest number of building permits. In the six largest counties (i.e., Harris, Dallas, Travis, Bexar, Collin and Tarrant) there were 34,038 new multi-family units, or 38% of the 88,833 housing starts in these counties. The map in Figure 6 shows these fast growing areas to be primarily in four metropolitan areas: the Houston area containing the fastest growing county (Harris county), the Dallas-Ft. Worth area containing four of the six counties (Dallas, Collin, Tarrant, and Denton), Travis county in the Austin metropolitan area, and Bexar county in the San Antonio area.

<sup>1</sup> The "2001 IECC" notation is used to signify the 2000 IECC (IECC 2000) as modified by the 2001 Supplement (IECC 2001), published by the ICC in March of 2001, as required by Senate Bill 5.

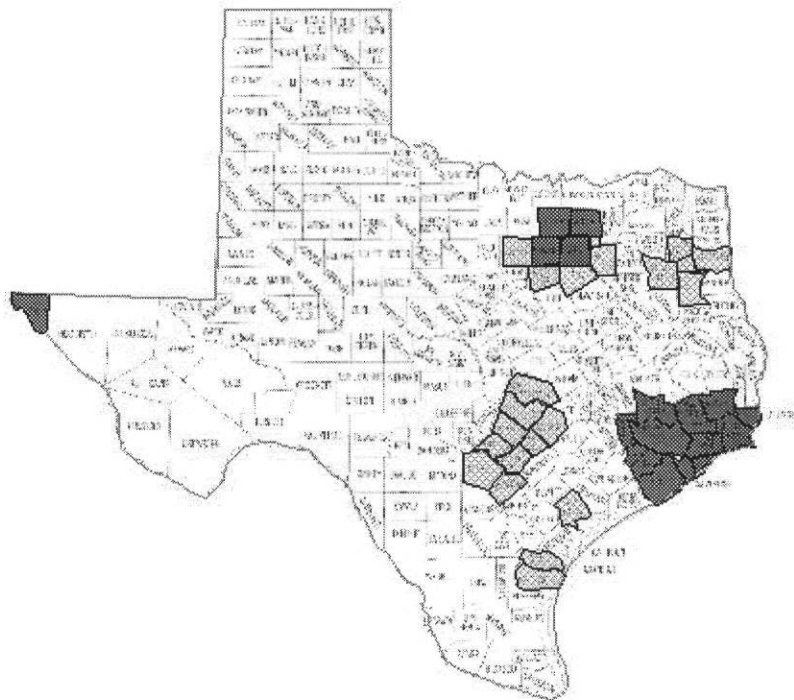


Figure 1: EPA Non-attainment (dark shade) and affected counties (light shade).

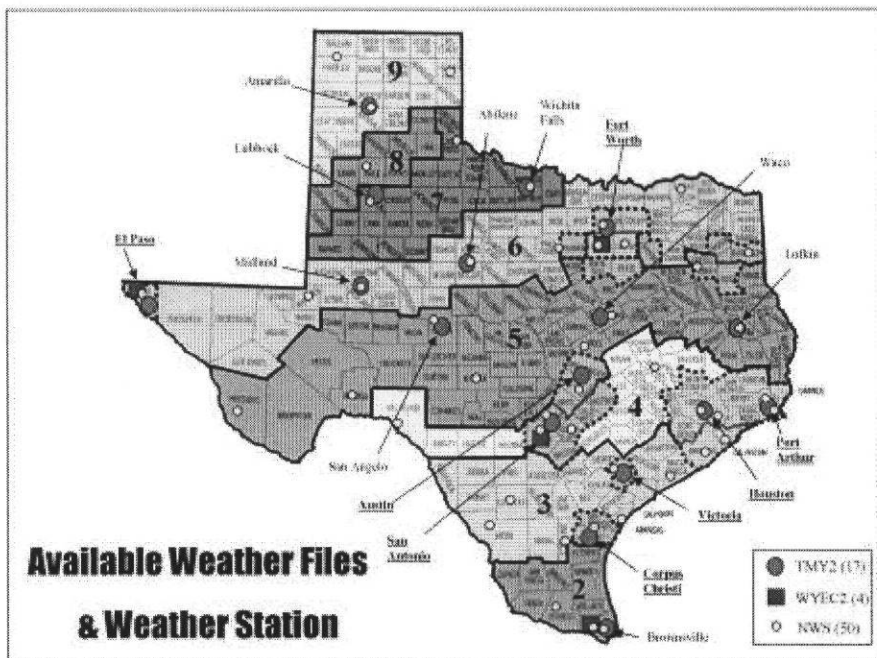


Figure 2: Available NWS, TMY2 and WYEC2 weather files compared to IECC weather zones for Texas.

### 1999 Texas County Population

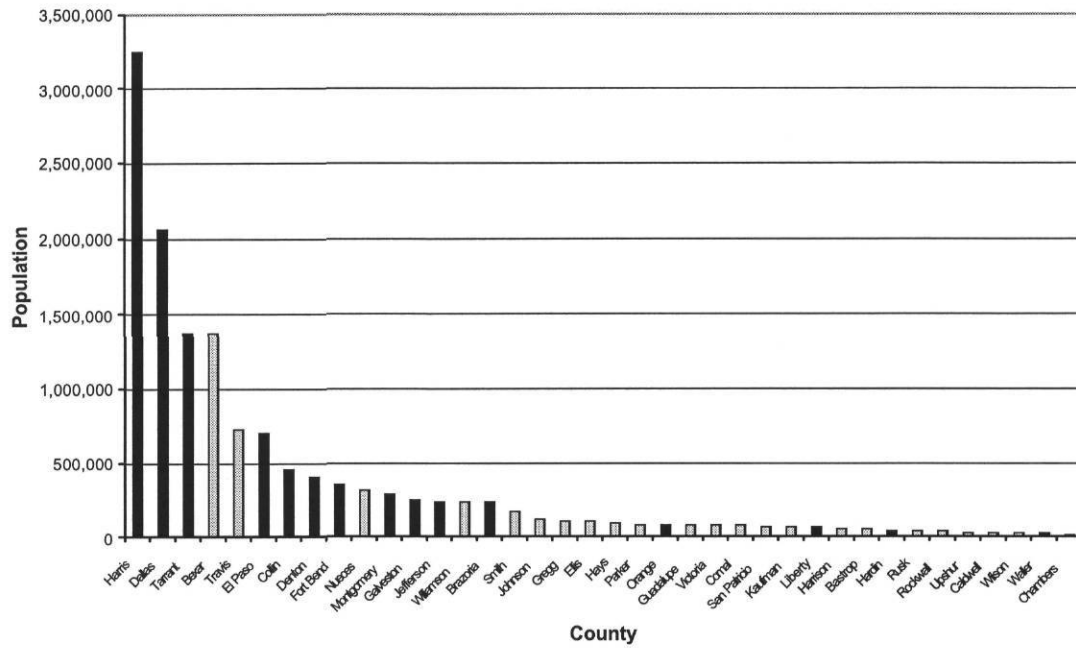


Figure 3: 1999 Texas county population for non-attainment (dark shade) and affected (light shade) counties (Source: U.S. Census)

### 1999 No. of Housing Units of Texas County

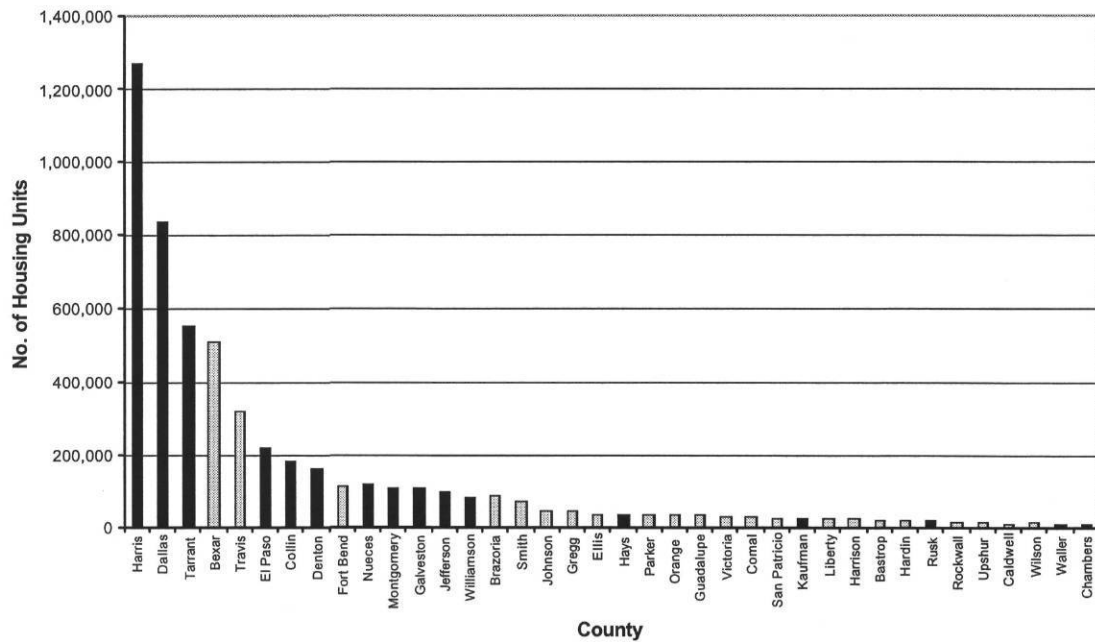


Figure 4: 1999 Housing units by county (Source: RECenter 2002).

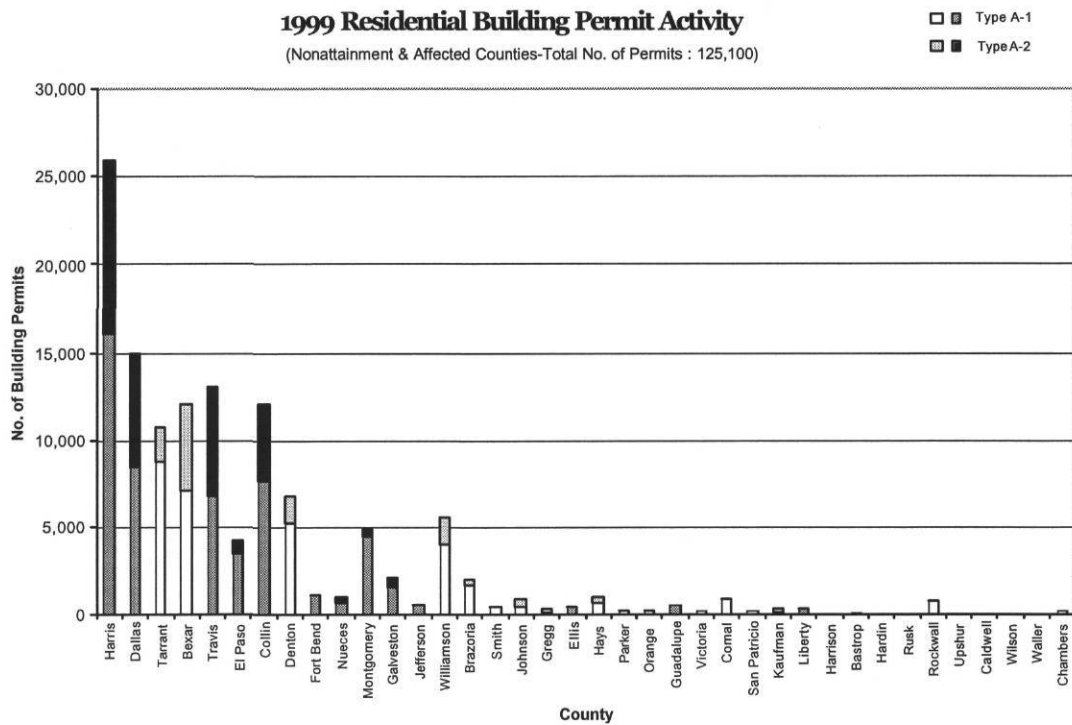


Figure 5: 1999 Residential building permits by county (Source: Real Estate Center, TAMU).

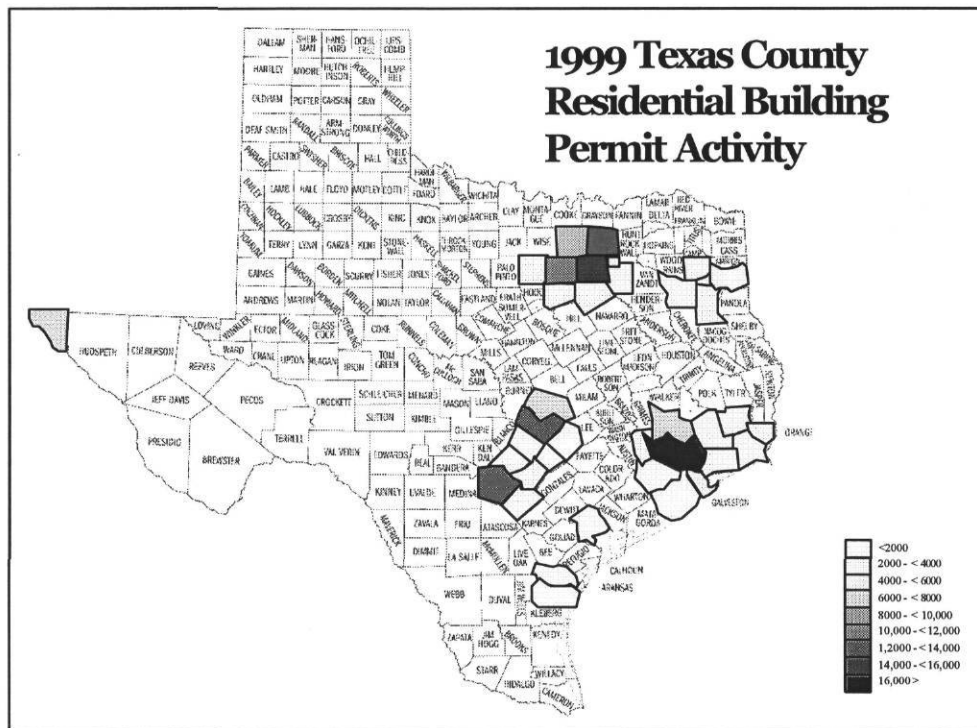


Figure 6: Map of 1999 residential building permits by county (Source: Real Estate Center, TAMU).



## 2.2 Energy Systems Laboratory's Responsibilities for Senate Bill 5.

Texas Senate Bill 5 has outlined the following responsibilities for the Energy Systems Laboratory (ESL):

- Sec. 386.205 - Evaluation Of State Energy Efficiency Programs.
- Sec. 388.003. Adoption Of Building Energy Efficiency Performance Standards.
- Sec. 388.004. Enforcement Of Energy Standards Outside Of Municipality.
- Sec. 388.007. Distribution Of Information And Technical Assistance.
- Sec. 388.008. Development Of Home Energy Ratings.

In the following sections each of these tasks is further described.

### 2.2.1 Section 386.205 - Evaluation Of State Energy Efficiency Programs (w/PUC).

In this section of Senate Bill 5, the Laboratory is instructed to assist the Texas Public Utilities Commission (PUC) and provide an annual report that quantifies by county, the reductions of energy demand, peak loads, and associated emissions of air contaminants achieved from the programs implemented under this subchapter and from those implemented under Section 39.905, Utilities Code (i.e., Senate Bill 7).

### 2.2.2 Sec. 388.003. Adoption Of Building Energy Efficiency Performance Standards.

This section of Senate Bill 5 adopts the energy efficiency chapter of the 2000 International Residential Code (IRC 2000) as an energy code for single family residential construction, and the 2000 International Energy Conservation Code (IECC 2000, including the 2001 supplement) for all other residential, commercial and industrial construction in the state. It requires that municipalities establish procedures for administration and enforcement, and ensure that code-certified inspectors perform inspections.

Senate Bill 5 Provides that local amendments, in non-attainment areas and affected counties, may not result in less stringent energy efficiency requirements. The Laboratory is to review local amendments, if requested, and submit annual report of savings impacts to TNRCC. The Laboratory is also authorized to collect fees for certain of its tasks in Secs. 388.004, 388.007 and 388.008.

### 2.2.3 Sec. 388.004. Enforcement Of Energy Standards Outside Of Municipality.

For construction outside of the local jurisdiction of a municipality, Senate Bill 5 provides for a building to comply if:

- a) a building certified by a national, state, or local accredited energy efficiency program shall be considered in compliance;
- b) a building with inspections from private code-certified inspectors using the energy efficiency chapter of the International Residential Code or International Energy Conservation Code shall be considered in compliance; and
- c) a builder who does not have access to either of the above methods for a building shall certify compliance using a form provided by the Laboratory, enumerating the code-compliance features of the building.

#### 2.2.4 Sec. 388.007. Distribution Of Information And Technical Assistance.

In this section of Senate Bill 5, the Laboratory is required to make available to builders, designers, engineers, and architects code implementation materials that explain the requirements of the International Energy Conservation Code and the energy efficiency chapter of the International Residential Code. Senate Bill 5 authorizes the Laboratory to develop simplified materials to be designed for projects in which a design professional is not involved. It also authorizes the Laboratory to provide local jurisdictions with technical assistance concerning implementation and enforcement of the 2000 International Energy Conservation Code and the energy efficiency chapter of the 2000 International Residential Code.

#### 2.2.5 Sec. 388.008. Development Of Home Energy Ratings.

Senate Bill 5 requires the Laboratory to develop a standardized report format to be used by providers of home energy ratings (HERs). It requires the form to be designed to give potential buyers information on a structure's energy performance, including certain equipment. Senate Bill 5 requires the Laboratory to establish a public information program to inform homeowners, sellers, buyers, and others regarding home energy ratings. It also requires the home energy ratings program to be implemented by September 1, 2002 .

### 3 ACCOMPLISHMENTS

#### 3.1 Section 386.205 - Evaluation Of State Energy Efficiency Programs (w/PUC).

##### 3.1.1 Held Preliminary Meetings with PUC to Discuss Procedures for Evaluating State Energy Efficiency Programs Created Senate Bill 5 Stakeholders Group

The Laboratory has had several meetings with the Texas Public Utilities Commission (PUC) to discuss the development of a framework for reporting emissions reductions from the State Energy Efficiency Programs administered by the PUC. The State Energy Efficiency Programs administered by the PUC include programs under Senate Bill 7 (i.e., Section 39.905 Utilities Code) and Senate Bill 5. In March of 2002 the PUC issued a Request for Proposals totaling \$400,000, which resulted in two grants being awarded in May of 2002.

During the period from May 2002 to October 2002 the Laboratory will be continuing to work with the PUC to help evaluate the energy savings and calculations of emissions reductions from the energy efficiency programs. For example, the Laboratory will be working with the PUC to help reformat the reported electricity savings in order to assure that they are compatible with the anticipated EGRID modifications.

#### 3.2 Sec. 388.003. Adoption Of Building Energy Efficiency Performance Standards.

##### 3.2.1 Created Senate Bill 5 Stakeholders Group

The Laboratory created a Senate Bill 5 Stakeholders Group consisting of manufacturers, public interest groups, builders, utilities, and Federal, State and Local government agencies. These Stakeholders meetings have provided the Laboratory with valuable input on how to best proceed with difficult issues that have had to be addressed in the first year of Senate Bill 5. Additional information about the Senate Bill 5 Stakeholders Group can be found on the Laboratory's web page.

##### 3.2.2 Builder's Guide (Version 1.04) Published

The Laboratory has produced a simplified Builder's Guide that provides builders with three prescriptive paths for each climate zone in Texas. This guide is available on the Laboratory's web site for downloading as a PDF file (i.e., [eslsb5.tamu.edu](http://eslsb5.tamu.edu)). Six thousand color copies of the Builder's Guide have also been printed and laminated to be distributed to builders to code officials to help simplify the implementation of the IECC. An example copy of the Builder's Guide is provided in the Appendix, Figure 46 and Figure 47.

##### 3.2.3 R-6 versus R-8 Flexible Duct Issue

In March of 2002 the Laboratory issued a technical memo regarding the use of R-6 flexible duct insulation instead of R-8 flexible insulation:

"The International Energy Conservation Code (IECC) of 2001 requires that R8 flexible duct be used in place of lower R-rated insulated duct, when ducts are in unconditioned space. Although R6 duct is widely and economically available, R8 insulated flexible duct is not at this time. Limited Supplies are available from one manufacturer but not in the quantities needed to satisfy the requirements for homes in municipal areas.

Chapter 11 of the International Residential Code (IRC) specifically allows R5 or higher in homes with up to 15% window to wall area. The IECC requires R8 for above 15% window to wall area. Situations where code inspectors have not allowed R6 duct in housing where the window to wall area is under 15% have been reported, undoubtedly due to confusion and inadequate training.

Technically, R6 insulated flexible duct causes minimal decrease in efficiency except when used in unconditioned attics. Use of R6 duct will result in a few percent loss of efficiency for the cooling system. Improper installation of either R6 or R8 that causes leakage will result in a much greater loss of system efficiency.”

This memo was the basis for the postponement of the use of R8 flexible duct (extended until February 1, 2003). A copy of Senator Brown’s letter is provided in the Appendix in Figure 50, Figure 51 and Figure 52. A copy of this letter is also posted on the Laboratory’s Senate Bill 5 web site.

#### 3.2.4 Submitted Code Amendment Review for NCTCOG, Including Energy Star as Above Code.

Pursuant to sec 388.003(e), the Laboratory received two requests for review of local amendments. The first was received from the North Central Texas Council of Governments for review of regionally recommended amendments to the model codes adopted as Texas Building Energy Performance Standards. Those amendments were determined to be substantially equal in stringency to the base codes -- and the regional approach was considered conducive to simplifying and improving compliance and enforcement for the region. There is some potential for results better than the base codes which has not been finally determined, but which will be a future focus of Laboratory simulation and verification efforts, as funding allows. The primary counties affected are: Dallas, Tarrant, Collin, Denton, Ellis, Kaufman, Rockwall, Johnson, and Parker.

The City of Houston also requested review of proposed amendments in August, 2002. That review is underway. Initial discussions with the City have indicated an intention that amendments would result in a small net increase in stringency and additional savings. A preliminary determination has not been completed but will help the City establish at least an equivalent level of stringency/savings, and a basis for identifying and verifying implementation results. The counties affected are Harris, Fort Bend, Montgomery and Liberty, within City of Houston jurisdictions only.

##### 3.2.4.1 Submitted Code Amendment Review for NCTCOG, Including Energy Star as Above Code.

The Laboratory was asked by the North Central Texas Council of Governments (NCTCOG) to review selected amendments to the 2000 IECC/IRC, including the use of Energy Star as an alternative compliance path to the 2000 IECC/IRC. The amendments submitted to the Laboratory and the Laboratory’s response are provided in the appendix. The request to approve the EPA’s Energy Star program is discussed in the next section.

##### 3.2.4.2 Submitted Code Amendment Review for City of Houston, Including Energy Star as Above Code.

The Laboratory was asked by the City of Houston to review selected amendments to the 2000 IECC/IRC, including the use of Energy Star as an alternative compliance path to the 2000 IECC/IRC. The amendments submitted to the Laboratory are still under review. The request to approve the EPA’s Energy Star program is discussed in the next section.

#### 3.2.5 Requested by EPA to Approve Energy Star as Above Code for Texas

As part of the request by the NCTCOG, the Laboratory was requested to approve the Energy Star program as an alternative compliance path. A similar request was also made by the City of Houston. The Laboratory reviewed the Energy Star program, including the computer simulation code used by the EPA<sup>2</sup>. The initial review precluded a blanket approval of the Energy Star program. The Laboratory reviewed selected

<sup>2</sup> This computer analysis for the Energy Star program is based on DOE-2.1e, ver. 121 simulations, which are performed by ICF Consulting, Washington, D.C., under contract to the U.S.E.P.A.

Building Option Packages (BOPs) for Houston and Dallas. As part of this review the Laboratory had extensive discussions with the EPA, ICF, the International Code Council (ICC), USDOE, PNNL, NREL and LBNL to determine how a code-traceable simulation could be developed and reviewed by experts at the USDOE's National Labs. Following the discussions the Laboratory then developed a code-traceable DOE-2 input file, and tested the Energy Star BOPs for Houston and Dallas.

Preliminary tests have shown that the Energy Star BOPs that were submitted to the Laboratory meet or exceed the prescriptive energy requirement of the IRC2000/IECC2000 with 2001 Supplement, after revisions were made<sup>3</sup>. A copy of the Laboratory's letter regarding the use of Energy Star is provided in the Appendix.

### 3.2.6 Requested to Approve REMRate and EnergyGauge USA as Alternative Compliance Path.

As part of the request by the NCTCOG, the Laboratory was requested to approve the REMRate and EnergyGauge USA software as an alternative compliance paths. A similar request was also made by the City of Houston. The Laboratory has developed a HERs Standardized Report that will facilitate the use of REMRate and EnergyGauge USA for this purpose. A copy of this report is included in the appendix.

### 3.2.7 Estimated NOx Reduction Potential From Implementation of the IECC/IRC to New Residences

The Laboratory has developed preliminary estimates of potential NOx reductions from the implementation of the IECC/IRC to new single-family residences. These estimates are based on the IECC-traceable DOE-2 simulation of an average-sized house as defined by the NAHB for 1999. It is anticipated that the implementation of the IECC/IRC will save between 1.7 and 2.5 tons-NOx/day. Additional information about these preliminary calculations can be found Section 7 of this report.

### 3.2.8 Development of an Analysis Plan to Report Energy Reductions and Link to Emissions Reductions

The Laboratory has initiated the development of several analysis plans to report the energy reductions from the implementation of the IECC/IRC to the TNRCC. The first procedure requires annual, countywide kWh reductions and peak kW reductions. The second procedure requires data and calculations from several state agencies, university labs and private entities. The second plan is being developed in cooperation with the Center for Energy and Environmental Resources (CEER) at the University of Texas, the Electric Reliability Council of Texas (ERCOT), and the Texas Public Utilities Commission (PUC). This plan is described in detail later in this report.

### 3.2.9 R-6 versus R-8 Flexible Duct Issue

In August 2002 the Laboratory, working closely with builders and duct manufacturers, developed an R-6/SEER 12 tradeoff method for building a house that complies with the 2000 IRC/IECC. A copy of this tradeoff method letter is provided in the appendix to the report.

## 3.3 Sec. 388.004. Enforcement Of Energy Standards Outside Of Municipality.

### 3.3.1 Self-Certification Form (Version 1.04) Published

The Laboratory has developed self-certification form for code compliance for residential buildings in unincorporated areas that is available for downloading as a PDF file at the Laboratory's web site (i.e., eslsb5.tamu.edu). An example of the self-certification form has been provided in the Appendix, Figure 48 and Figure 49. This two-page form provides a simplified check list for a builder to use to self-certify that they are compliant with the 2000 IECC/IRC (including the 2001 Supplement).

<sup>3</sup> These revisions include: mandating SHGC < 0.40 for HDD < 3,500, double pane windows, referencing window area to wall area, and revising the footnotes on the BOPs to comply with the IECC/IRC.

### 3.3.2 Implementation Date

At the first Senate Bill 5 stakeholder's meeting, the Laboratory was asked to help resolve the issue regarding the implementation date for compliance with Senate Bill 5. The Laboratory issued a technical memo recommending a delay, in accordance with a memo regarding legislative intent from Senator Brown. The Texas Attorney General then ruled that the start date was to be September 1<sup>st</sup>, 2001.

## 3.4 Sec. 388.007. Distribution Of Information And Technical Assistance.

### 3.4.1 Web Site Operational "eslsb5.tamu.edu"

The Laboratory has established a Senate Bill 5 web page (i.e., eslsb5.tamu.edu), where information is provided to builders, code officials, and homeowners about Senate Bill 5, including: the Builder's prescriptive compliance form (B&W or color PDF), the Builder's self-certification form, the Laboratory's letter regarding the R8 flexible duct issue, information about the Laboratory's communications to the Texas Legislature, news articles, and related contacts. Figure 7 illustrates the Laboratory's Senate Bill 5 web page.

### 3.4.2 Provide Training Sessions

The Laboratory has provided (29) IECC/IRC code training workshops at the following locations in Texas (Supported under State Energy Program DOE funding through SECO):

- |                     |                      |
|---------------------|----------------------|
| •Austin (2)         | •El Paso             |
| •Bonham             | •Amarillo            |
| •Galveston          | •Laredo              |
| •Longview           | •Houston             |
| •Lubbock            | •College Station (4) |
| •McAllen            | •Kerrville           |
| •San Antonio        | •Beaumont            |
| •Corpus Christi (2) | •San Angelo          |
| •Victoria           | •Tyler               |
| •Abilene            | •Dallas              |

### 3.4.3 Responding to About 40 to 60 Calls Per Week

The Laboratory responds to about 40 to 60 phone calls per week, which include questions about the IECC/IRC from Builders, HVAC Contractors, Window Manufacturers, Door Manufacturers, Duct Manufacturers, code officials, and homeowners. A database is being established to track questions and responses. A frequently asked questions (FAQ) feature is also being established for the Laboratory's Senate Bill 5 web page.

### 3.4.4 Delivered Senate Bill 5 Sessions at Hot and Humid Conference

To help foster technology transfer in Houston, the Laboratory worked closely with the Planning Committee for the 13<sup>th</sup> Symposium on Improving Building Systems in Hot and Humid Climates to include a plenary session and a panel session on Senate Bill 5. The 13<sup>th</sup> Symposium was held in Houston on May 20 – 22, 2002 and was well attended. The invited plenary speaker on May 20<sup>th</sup> was Commissioner Ralph Marquez, who spoke about the pollution problems in Houston and how Senate Bill 5 was created to help address these problems. The Senate Bill 5 panel session included two papers<sup>4</sup>, and three additional presentations<sup>5</sup>.

<sup>4</sup> The papers published in the Proceedings include: Haberl, J., Culp, C., B. Yazdani, T. Fitzpatrick, D. Turner. 2002. "An Introduction to Texas Senate Bill 5", Proceedings of the Thirteenth Symposium on Improving Building Systems in Hot and Humid Climates, Texas A&M University, Houston, Texas, and

### 3.4.5 Delivered 'Building Energy Codes and Technologies' at the TCET Symposium for Reducing Emissions in Texas, May 21, 2002, Houston, Texas.

The Laboratory was also asked to develop and deliver panel on Building Energy Codes and Technologies for the May 21<sup>st</sup>, 2002 Symposium on Technology for Reducing Emissions in Texas, presented by the Texas Council on Environmental Technology, in cooperation with the Texas Natural Resources Conservation Commission, which was also presented in Houston. This panel was composed of Dr. David Claridge, ESL, Dr. Charles Culp, ESL, Mr. Mani Palani, UT Health Science Center, and John Hoffner, Conservation Services Group.

## 3.5 Sec. 388.008. Development Of Home Energy Ratings.

### 3.5.1 Working Toward a Standard Input File for Code Compliance Testing

The Laboratory has developed a code-traceable DOE-2 input file for calculating energy savings and demand reductions from implementation of the IECC/IRC statewide. These simulations are needed for analyzing the energy savings from proposed municipality code amendments, and annual calculation of IECC statewide savings. The Laboratory has also developed a HERs Standardized Report, which is included in the appendix to this report.

### 3.5.2 Development of HERs Standardized Report.

The Laboratory developed a standardized Home Energy Rating format for reporting the results. A copy of this form is provided in the appendix to this report.

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Haberl, J., Culp, C., B. Yazdani, T. Fitzpatrick, D. Turner. 2002. "Texas' Senate Bill 5 Legislation for Reducing Pollution in Non-attainment Areas: Procedures for Measuring Pollution Reduction from the Adoption of the International Energy Conservation Code (IECC/IRC 2001)", Proceedings of the Thirteenth Symposium on Improving Building Systems in Hot and Humid Climates, Texas A&M University, Houston, Texas.

<sup>5</sup> The additional presentations include an overview of Senate Bill 5 by Bill Jordon, TNRCC, a report on the PUC's efforts towards compliance with Senate Bill 5 by Jess Totten, PUC, and a report by Ken Donohoo from ERCOT.



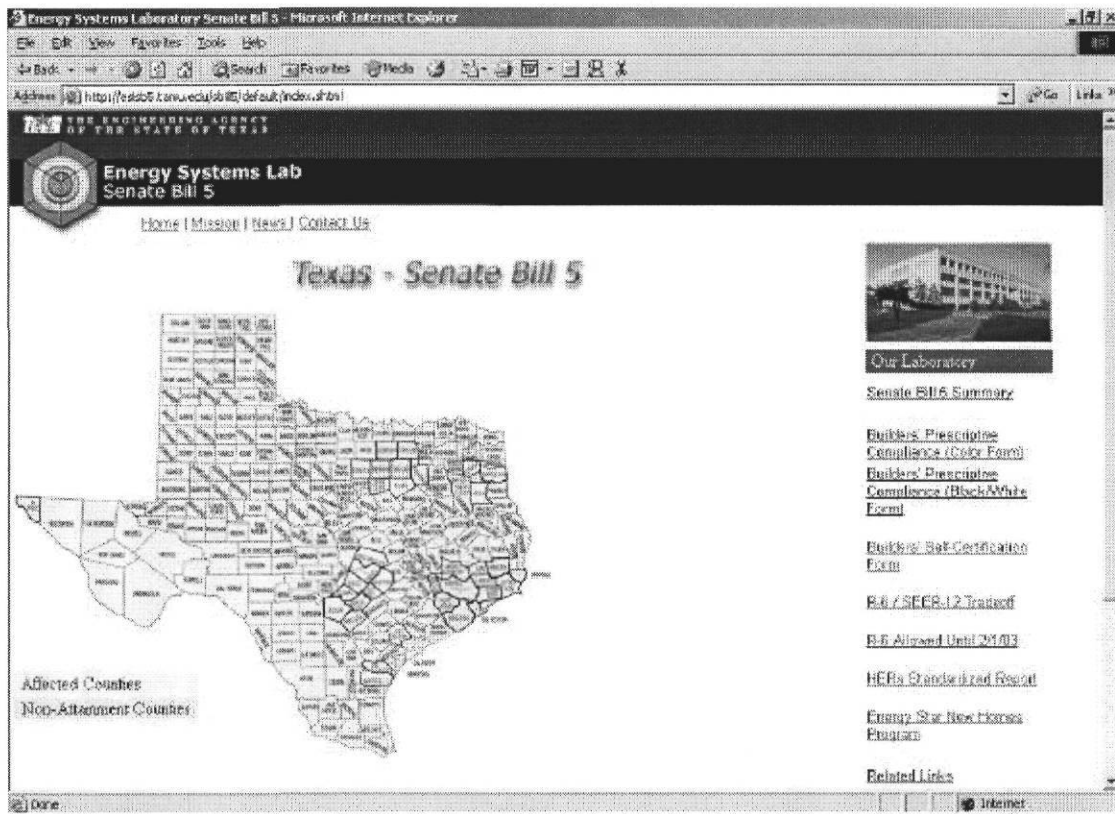


Figure 7: Laboratory's Senate Bill 5 web page for providing information about implementing the IECC/IRC.



## 4 RECOMMENDATIONS

The Energy Systems Laboratory makes the following recommendations to the TNRCC concerning Senate Bill 5. These recommendations are organized into three (3) groups, including: 1) Recommendations for Additional NOx Savings Measures Not Covered in Current Legislation. 2) Recommendations for Improving the Documentation of Emissions Reductions. 3) Other Recommendations

### 4.1 Recommendations for Additional NOx Savings Measures Not Covered in Current Legislation.

#### 4.1.1 Recapture and Document the Energy Savings in Texas LoanSTAR and Rebuild America Programs Currently in Place.

##### 4.1.1.1 Background: LoanSTAR Program.

The Texas LoanSTAR (Loans to Save Taxes And Resources) Program was established in 1988 by the Texas Governor's Energy Office (GEO) as a revolving loan program for funding energy conserving retrofits in state and local government buildings. The program has been very successful. One of the important features of the LoanSTAR program is the Monitoring and Analysis Program developed by the Energy Systems Laboratory that measures and reports energy savings from the retrofits using hourly before-after measurements in sites where the cost of the retrofit exceeds \$100,000. At such sites data acquisition systems are ideally installed six to twelve months prior to the retrofit to monitor energy consumption so that an hourly whole-building, before-after analysis can be used as the basis for calculating savings.

As of April 2002 there were \$74.5 million in measured/stipulated retrofits savings from 32 loan sites (298 buildings), \$10.4 million in estimated savings from 98 sites using annual comparisons, \$27.6 in Continuous Commissioning<sup>SM</sup> savings<sup>6</sup>, for a total program savings of \$112.7 million<sup>7</sup> as shown in Figure 8. In Figure 9 the \$78 million<sup>8</sup> of measured retrofit savings are broken down into their measured electricity (41%), cooling (42%) or heating (37%) components. In Figure 10 the yearly savings from the LoanSTAR program are shown, including \$27.6 in Continuous Commissioning<sup>SM</sup> savings which began in 1993 and grew until 1997<sup>9</sup>. It is interesting to note that these savings are 117% of the audit-estimated savings, which were estimated by the engineering consultants who designed the retrofits under contract to SECO. The success of LoanSTAR's measured savings has been recognized by the USDOE and USEPA as a model program for its effectiveness and ground-breaking work. The data analysis methods developed in the program have also been adopted as the basis for the before-after (Option C) and the calibrated simulation procedures (Option D) in the North American Energy Measurement and Verification Protocols (NEMVP 1996), and the basis for the before-after and calibrated simulation methods in Guideline 14P under development by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE Guideline 14P 2002).

Another benefit of the measured LoanSTAR savings has been the ability to calculate potential emissions savings from the energy conservation (Athar et al. 1998). As of April 2002, the total potential emissions reductions for the measured retrofit savings for the period 1990 to 2002 amounted to 4,110 tons NOx, 1.2 million tons CO<sub>2</sub>, and 2,667 tons SO<sub>2</sub>, as shown in Figure 11. Furthermore, since the energy savings were

<sup>6</sup> The term "Continuous Commissioning<sup>SM</sup> or CC<sup>SM</sup>" refers to the technology developed by the Energy Systems Laboratory whereby the Laboratory, working closely with the building operators, uses continuous energy use monitoring, to optimized the HVAC system's operation, reduce and then maintain its reduced energy use. The Laboratory is currently working closely with the Texas State Energy Conservation Office to help transfer this technology to the HVAC industry in Texas through a series of workshops. The Laboratory also works directly with Texas State Agencies to apply Continuous Commissioning<sup>SM</sup> to individual facilities.

<sup>7</sup> Savings include \$3.2 million in savings overlap between retrofit savings and Continuous Commissioning<sup>SM</sup> savings.

<sup>8</sup> The \$78 million in metered savings include \$3.3 million in savings which are also included in the Continuous Commissioning<sup>SM</sup> savings shown in Figure 8.

<sup>9</sup> During the period from 1993 to 1997 Continuous Commissioning<sup>SM</sup> was funded as part of the LoanSTAR program. Since 1997 Continuous Commissioning<sup>SM</sup> procedures have also been applied to the Texas A&M University campus, resulting in a savings of more than \$3 million per year. LoanSTAR funding has also paid for Continuous Commissioning<sup>SM</sup> at Texas Tech University, which has resulted in \$250,000 in savings for the period 2000 - 2002.

primarily derived from hourly measurements, potential emissions savings can be broken-down into heating (1,087 tons), cooling electric (649 tons), and other electric (2,374 tons) savings, which help to indicate which energy conserving features are most likely to contribute to NO<sub>x</sub> reductions.

For example, although both heating and cooling have similar thermal energy reductions (i.e., 3.1 vs 2.8 million MMBtu, respectively), it is interesting to note that energy conservation retrofits involving heating has significantly more NO<sub>x</sub> reductions. However, the majority of the heating NO<sub>x</sub> reductions occur in the winter when ozone formation from NO<sub>x</sub> does not rise above EPA limits. Therefore, calculating tons of NO<sub>x</sub> per day by dividing annual total NO<sub>x</sub> reductions (i.e., heating, cooling and electricity) would over-emphasize heating reductions and under-emphasize cooling reductions<sup>10</sup>.

Although the LoanSTAR program has been successful in its measurement of energy savings much can be done to strengthen and improve the LoanSTAR program as is evident when one takes a closer look at the details. For example, in Figure 12 the total annual LoanSTAR retrofit expenditures and savings are shown for the period 1991 to 2000 (Kumar et al. 2002). By 1991, the first year of recorded savings, the program had loaned \$17,770,965. LoanSTAR reached a peak of \$55,635,428 in loans in 1996, and decreased to an annual funding level of \$27,281,071 in 2000. Since 1991 the measured and actual savings for the total program have closely tracked each other, beginning with an annual measured savings of \$1,134,357, rising to a peak savings of \$11,018,930 in 1997, decreasing to an annual savings of \$794,678 in 1999, and rising back to \$930,890 in 2000.

In the LoanSTAR program the metering costs are fixed at 3% of the retrofit costs, and about 1 – 2% per year for reporting an analysis. A review of the Annual Energy Consumption Reports (AECR) submitted to SECO reveal that several “trends” are observable when we compare the estimated vs. actual energy savings. First, is the fact that the estimated energy savings can over or under-predict the actual savings from about 45% to almost 300% emphasizing the need for verification of energy savings.

Second, in Figure 13, the multiyear realization rates are shown for all LoanSTAR buildings from 1991 to 2000, which range from –100% to +300% for individual buildings. The annual program average displayed as a solid line, which began at 114% in 1991, rose to a peak of 121% in 1994, dropped to a low of 63% in 1998 and rose back to 85% in 2000. Finally, in Figure 14, the actual savings (x-axis) are plotted against the estimated savings (y-axis) using a line to connect the points to show the behavior of the loan over time. This figure has helped to verify several features of interest. First, very few individual sites cluster around the diagonal line, which would represent complete agreement between estimated and actual savings. Sites that have a horizontal line represent sites where the estimated savings remained the same, but the actual savings varied over the life of the loan. This is in contrast to sites that have a vertical line, which represents sites where the actual savings remained the same, but information was discovered about the estimated savings that caused the value of the loan to change. Sites with varying diagonal lines contain a combination of changes to the actual and estimated savings. Several sites actually zig-zag back and forth indicating both positive and negative changes to either the estimated or actual savings – clearly a testament to the value of accurate measured savings.

These findings are consistent with other analysis that confirm the need for continuous monitoring of savings from energy conservation retrofits. Specifically, these analysis show that the sites with utility bill tracking only showed 70% savings whereas the sites with hourly measured data produced 100 – 110% savings and M&V with hourly data and a carefully administered commissioning program can produce 120 – 150% of audit retrofit savings reinforcing the results from earlier studies (Claridge et al. 1994; Claridge et al. 1996; Kats et al. 1996).

<sup>10</sup> NO<sub>x</sub> emission reductions which are attributable to cooling-related savings occur primarily in the summer when ozone is problematic for several areas of Texas. Procedures for accurately calculating ozone reductions require hourly electricity savings data, as well as an hourly electric grid distribution model, hourly weather data, and the appropriate power generation dispatch models.

#### 4.1.1.2 Background: Rebuild America Program.

The Rebuild America program is network of community-based partnerships that rebuilds communities by promoting the efficient use of energy. Rebuild America is coordinated at the national level by sponsorship through the Office of Energy Efficiency and Renewable Energy at the United States Department of Energy (USDOE). Rebuild America has 250 partnerships in 47 states, Native American Tribes and in three U.S. Territories. Rebuild America's goal is to reduce the energy use in participating communities by 20-30%, which would amount to a savings of \$650 million by 2003 and air pollution reductions of 1.6 million tons of carbon dioxide (USDOE 2000).

Rebuild America was first began in Texas with the Brazos Valley Energy Conservation Coalition (BVECC), which has been a Rebuild America partner since 1996. Since 1996 BVECC has contacted over 57 facilities in Texas about joining Rebuild America. Twenty-five of these facilities have authorized BVECC to conduct walk-through audits, and fourteen preliminary walk-through audits have been performed. As of June 1999 nine facilities have joined the Rebuild America program covering a total of 8 million square feet of conditioned area. The total estimated retrofit project costs for these 9 facilities are over \$11 million, with annual savings of \$2.6 million, and an estimated 4.3 year payback. The original BVECC members and their associated responsibilities include program administration, monitoring and commissioning to be provided by the ESL, engineering services to be provided by the Texas Energy Engineering Services, Inc., (TEESI 2000), the City of Bryan (COB) and the Bryan Utilities (now Bryan Texas Utilities; BTU 2000) who provided many of the initial clients, and commercial financing provided by Smart Energy Systems (SES 2000).

The Brazos Valley Energy Conservation Coalition (BVECC) is now one of many Rebuild America Partners in Texas, which include: Rebuild Texas, the City of Texas City, Texas Christian University, EnerSource Capital, and the East Austin Economic Development Corporation. Beginning in 2002, Rebuild America is now coordinated by the Texas State Energy Conservation Office.

#### 4.1.1.3 Recapture and Document the Energy Savings in Texas LoanSTAR and Rebuild America Programs Currently in Place.

Currently, Texas has documented over \$100 million in energy savings in hundreds of buildings around the State of Texas. However, Measurement and Verification (M&V) on most of these buildings has been discontinued when the loans were paid back. Several studies by the Laboratory have shown that 20 to 30%+ of the savings will erode over time if these buildings are not carefully monitored using standardized procedures<sup>11</sup>.

Therefore, it is estimated that restarting the monitoring in these buildings and recommissioning the HVAC systems will likely produce \$2.0 to 3.4 million per year in real dollar savings to Texas taxpayers, and will have verifiable emissions reductions because of the hourly measurements. The potential NO<sub>x</sub> emissions reductions are estimated to be 37 to 62 tons-NO<sub>x</sub>/yr, or 0.1 to 0.17 tons-NO<sub>x</sub>/day (See Appendix for details). The cost associated to restart the LoanSTAR M&V and to perform commissioning is estimated to be \$5.2 million for the first year and \$260,000 per year to collect, process and report the measured energy reductions. This results a \$9,703 - \$16,250 \$/ton-NO<sub>x</sub>-10yr cost, or \$26.58 - \$89.28 \$/ton-NO<sub>x</sub>-10yr-day.

<sup>11</sup> Additional information about this can be found in the papers: Kumar, S., Haberl, J., Claridge, D., Turner, D., O'Neal, D., Sharp, T., Sifuentes, T., Lopez, F., Taylor, D., "Measurement and Verification Reality Check: A Yawning Gap Between Theory and Practice", Proceedings of the 2002 ACEEE Summer Study, (August); and Claridge, D., Liu, M., Deng, S., Turner, D., Haberl, J., Abbas, M., Bruner, H., Veteto, B., Lee, S. 2001. "Cutting Energy and Cooling Use Almost in Half Without Capital Expenditure in a Previously Retrofit Building", Proceedings of the Summer Study of the European Council for an Energy Efficient Economy (ECEEE), June 11-16, 2001, Mandelieu, Cote D'Azur, France.

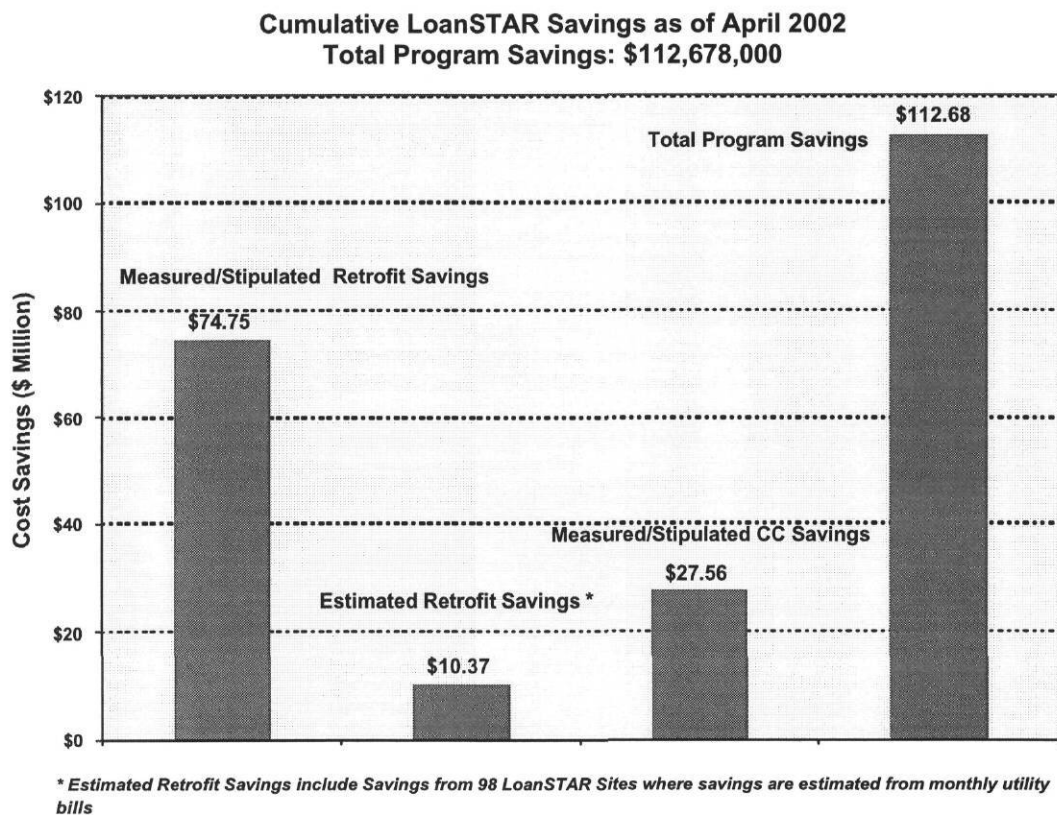


Figure 8: Cumulative total LoanSTAR savings: 1990 – 2002

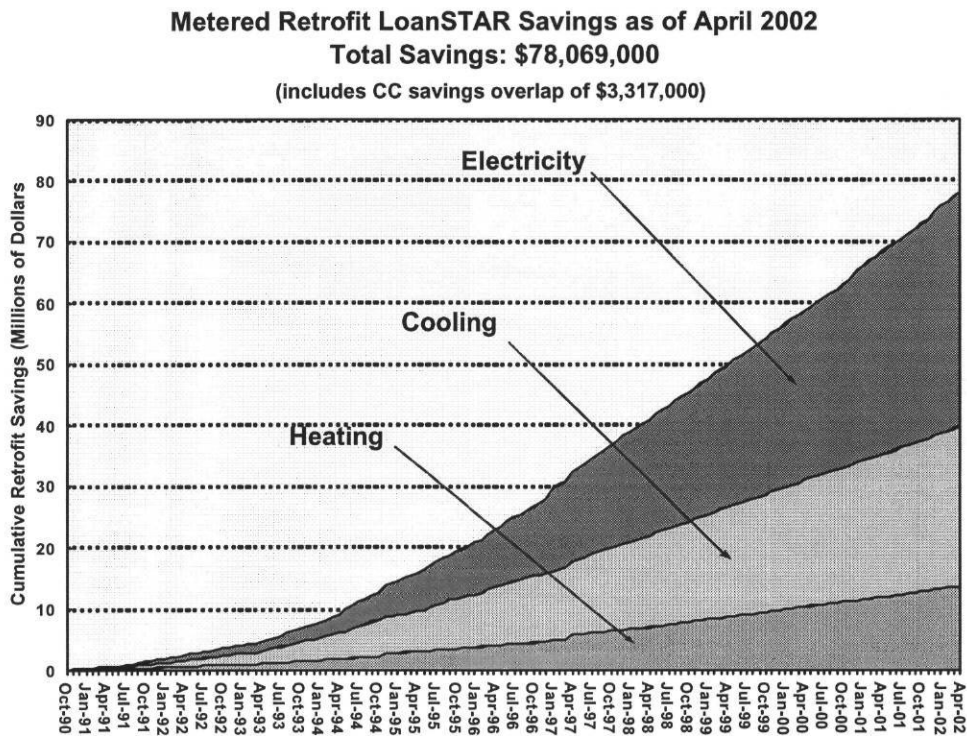


Figure 9: Cumulative metered LoanSTAR retrofit savings: 1990 – 2002.

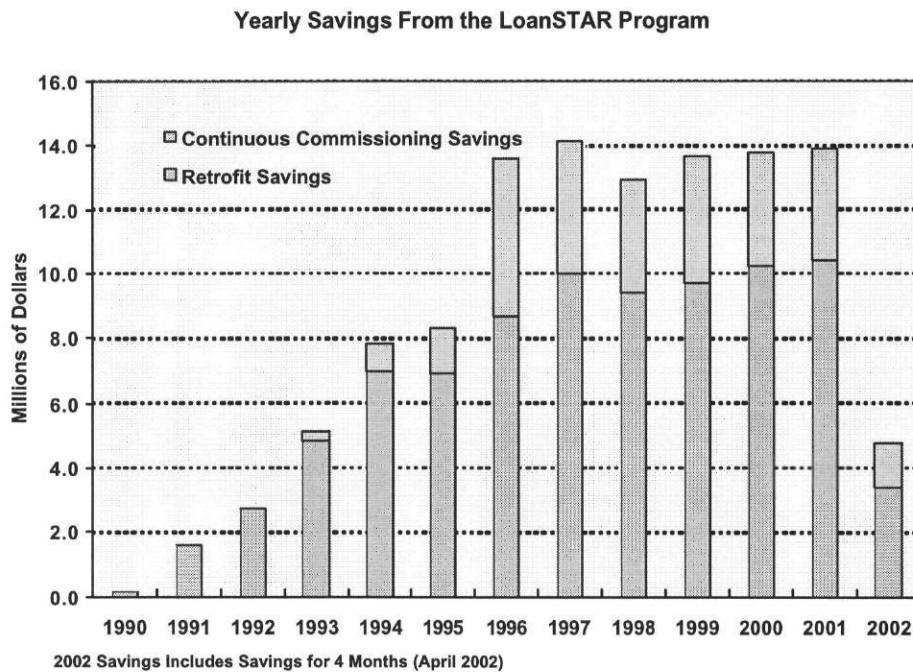


Figure 10: Yearly savings from the LoanSTAR program including Continuous Commissioning<sup>SM</sup> for the period 1990 – 2002.



### Emissions Savings Summary (As of April 2002)

	NO <sub>x</sub> Tons	CO <sub>2</sub> Tons	SO <sub>2</sub> Tons
<b>HEATING</b> (3,053,108 MMBtu)	1,087	237,135	1.19
<b>CHILLED WATER</b> (2,832,764 MMBtu)	649	200,654	572
<b>ELECTRICITY</b> (863,216 MWh)	2,374	733,733	2,093
<b>TOTAL SAVINGS</b>	<b>4,110</b>	<b>1,171,522</b>	<b>2,667</b>

The combined reduction in pollutants in tons resulting from heating, cooling, and electricity savings  
The numbers in parantheses are the total heating, cooling , and electricity savings from the LoanSTAR sites  
Figure 11: LoanSTAR's potential for emissions savings: 1990 – 2002.

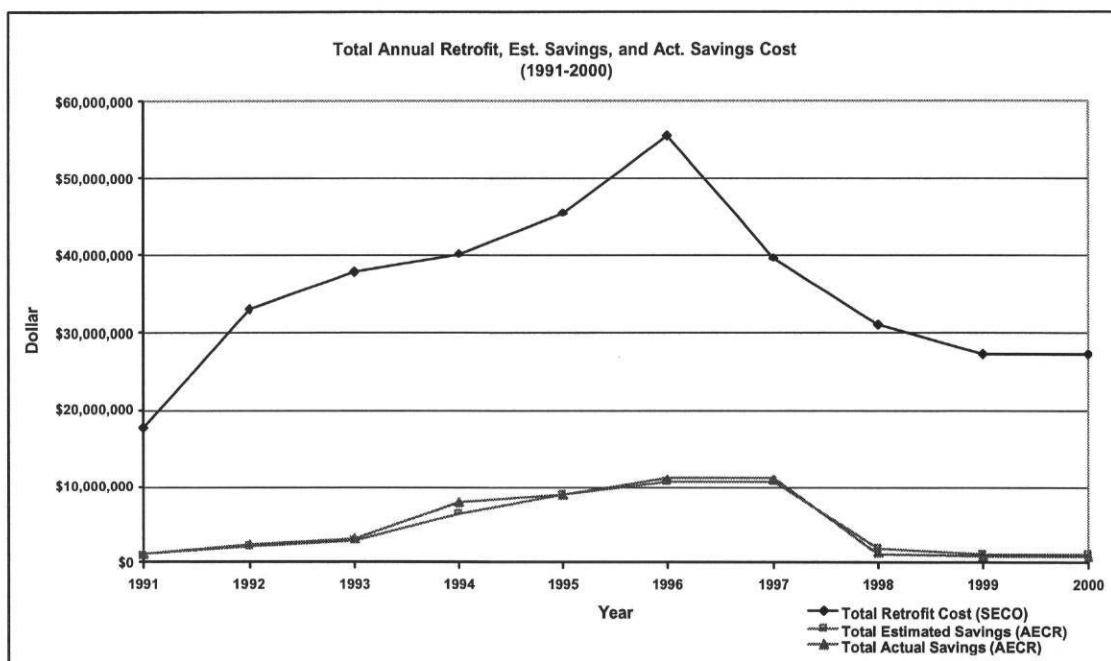


Figure 12: Total annual LoanSTAR retrofit expenditures and savings: 1991 – 2000.

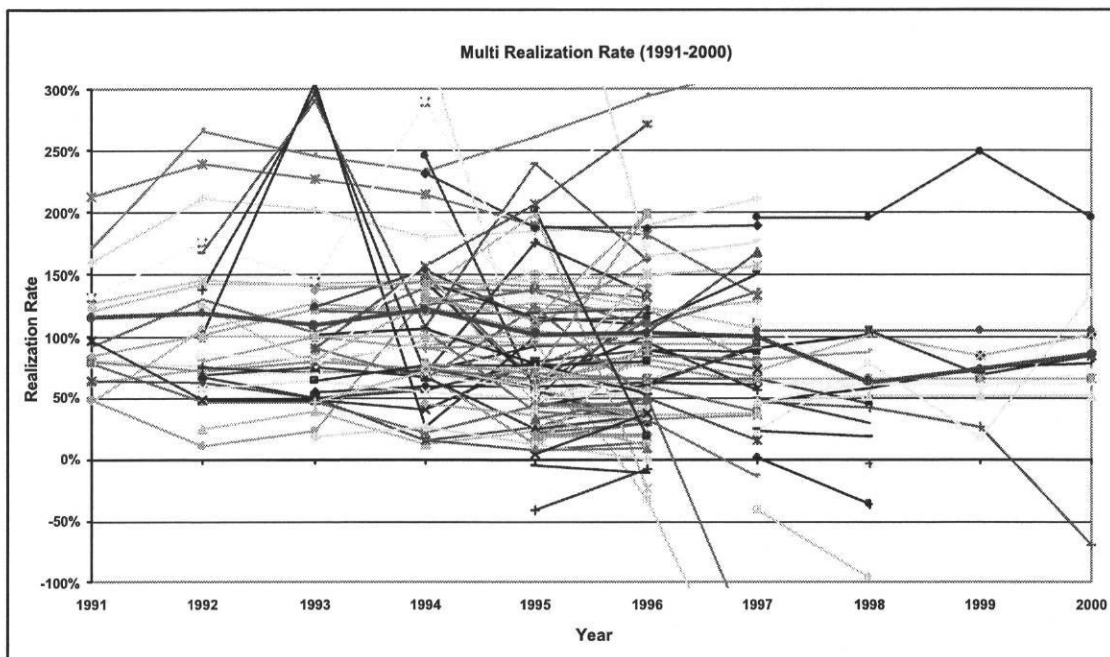


Figure 13: Multi-year realization rate for LoanSTAR buildings (building data: 1991-2000).

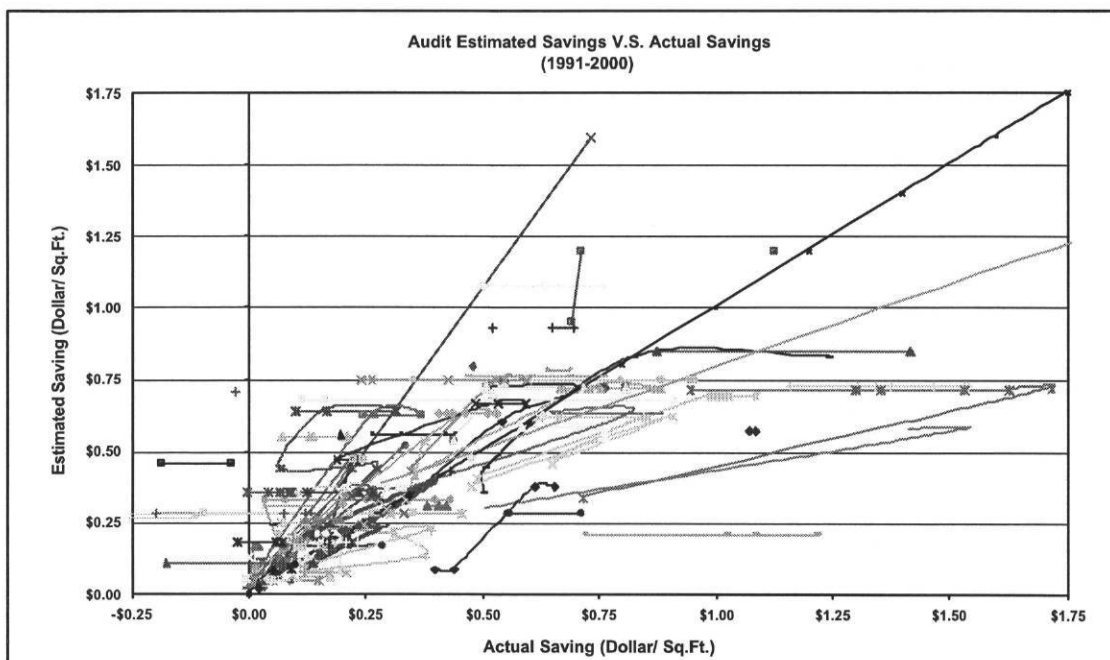


Figure 14: Multi-year realization rate for LoanSTAR buildings (profiles: 1991 – 2000)

#### 4.1.2 Reducing NOx Emissions by Changing Consumer Purchases.

The current version of the IECC/IRC does not include a direct provision for reducing the energy use of a residence by improving the appliance energy efficiency, including lighting efficiency use in residences. Although appliance energy efficiency is currently regulated by national standards, significant state-wide electricity savings could be generated and, credits measured for emissions credits if the proper procedures were in developed for accomplishing this.

The potential NOx reductions from several consumer-purchase options have been investigated and are reported in the following sections, with detailed calculations in the appendix, including:

- Motivating consumers to purchase SEER 12 air conditioners.
- Increased use of efficient refrigerators.
- Increased use of efficient clothes washers.
- Increased use of Low-E windows.
- Increased use of solar thermal DHW systems.
- Increased use of compact fluorescents.
- Elimination of pilot lights.

These recommendations are provided so that the Senate Bill 5 policy makers will have preliminary NOx reductions estimates for a range of new policy areas that show potential for further study. Many of the values shown represent the maximum potential estimates for NOx reductions and would require substantial investments over a series of years. Therefore, detailed study is recommended for each of the measures listed before legislation is created.

##### 4.1.2.1 Example: Motivate Consumers to Purchase SEER 12 Vs Today's Average SEER 11

Currently, the 2000 IECC/IRC requires the use of SEER 10 air-conditioner for new residential construction, which is at or slightly below the average air conditioner efficiency, and below the current Federal SEER 10 standards for residential central air conditioners and heat pumps, which are scheduled to go to SEER 12 in 2006<sup>12</sup>. A review of the Air Conditioning and Refrigeration Institute (ARI) sales information for single phase units (65,000 Btu/h or less) in Texas revealed that 716,024 units were sold in 1999, of which 0.9% were less than SEER 10, 62.2% were between SEER-10 and SEER-11, 2.5% were between SEER-11 and SEER-12, 29.8% were between SEER-12 and SEER-13, and 4.6% were above SEER 13 (see Appendix for details).

Therefore, if all new air-conditioning units could be SEER 12 or better, it is estimated that 756,000 new air conditioners would be installed in 2003, of which 260,000 are already SEER 12 or better and 70,000 are accounted for in the PUC's Senate Bill 5 and Senate Bill 7 program, leaving 426,000 units that could be credited to reducing NOx from an efficiency upgrade. These 426,000 units would consume 529 to 1,146 kWh/year less, which amounts to 247,889 to 537,016 MWh/yr, which is estimated to be 191 to 414 tons-NOx/yr or an average 0.5 to 1.1 tons-NOx/day. The NOx emissions during peak summer periods is estimated to be 1.6 to 3.6 tons-NOx/day. The cost associated with this upgrade is estimated to be \$200 to \$500 per unit, or \$20,604 to \$111,591 \$/ton-NOx-10yr, which is \$56 to \$306 \$/ton-NOx/10yr-365day.

##### 4.1.2.2 Example: Improved Refrigerator Efficiency

Energy efficiency of residential refrigerators varies significantly from manufacturer to manufacturer, with more efficient models arriving daily at appliance stores. Unfortunately, most consumer purchases are based primarily on cost, brand name identification, and features. Energy efficiency can easily vary from 100 to

<sup>12</sup> There is also a need to motivate customers to purchase window air conditioners and commercial air conditioners that are above the Federal standards.



more than 150 kWh/year for an average sized refrigerator using the U.S.D.O.E. Energy Guide values, and has no relationship to the cost of the refrigerator<sup>13</sup> (See Appendix for details).

Therefore, if new energy efficient refrigerators could be installed in 75% of the 8.8 million Texas households it is estimated that 728,516 to 1,092,775 MWh/yr could be saved, which results in 617 to 926 tons-NOx/yr, or 1.7 to 2.5 tons-NOx/day. The cost associated with this recommendation is about \$100 per refrigerator, which would be \$662 million state-wide, resulting in \$71,554 to 107,331 \$/ton-NOx-10yr, or \$196 to \$294 \$/ton-NOx-day.

#### 4.1.2.3 Example: Improved Clothes Washer Efficiency

Unlike refrigerators, the energy efficiency of clothes washers is highly dependent on what kind of washer, with horizontal axis machines having the edge over vertical axis machines. Savings also varies significantly from manufacturer to manufacturer, with more efficient, less expensive horizontal axis models arriving daily at appliance stores. Unfortunately, most consumer purchases are based primarily on cost, brand name identification, and features. Energy efficiency can easily vary from 300 to 400 kWh/year using the U.S.D.O.E. Energy Guide values for clothes washers. Horizontal axis clothes washers also use considerably less water as well (See appendix for details).

Therefore, if new energy efficient clothes washers could be installed in 90% of the 8.8 million Texas households, it is estimated that 2.6 to 3.5 million MWh could be saved, which results in 2,221 to 2,962 tons-NOx/yr or 6 to 8 tons-NOx/day. The cost associated with this is estimated to be \$2.4 to 5.5 billion, state-wide, which results in \$107,331 to 187,829 \$/ton-10yr, or \$294 to \$515 \$/ton-NOx-day.

#### 4.1.2.4 Example: Increased Use of Compact Fluorescent Lamps

New energy efficient lighting, such as compact fluorescents, also offers significant savings in energy use when compared to traditional light sources, such as incandescents. For example, a 60 Watt incandescent can now be replaced with a similar sized lamp that provides the same amount of light, and yet only uses 15 Watts of energy. Compact fluorescents also last considerably longer than incandescents, usually about 6,000 hours (see Appendix for details).

If every residence in Texas could be motivated to install 10 compact fluorescents, then it is estimated that electricity use would drop by 657 kWh/house, which would result in 6.4 to 7.7 million MWh, which is 4,914 to 6,006 tons-NOx/yr, or 13.5 to 16.5 tons-NOx/day. The cost associated with this would be \$573 to \$662 million, or \$52,510 to \$55,622 \$/ton-NOx-yr, which is \$152 to \$144 \$/ton-NOx-10yr-day.

#### 4.1.2.5 Example: Accelerate the Use of Low-E Replacement Windows

Clearly, the installation of Low-E windows in new construction contributes significantly to the energy reductions versus a standard house with average windows as defined by the NAHB survey data. However, if Low-E windows could be installed in 90% of the houses in the state, then significant NOx reductions can be calculated as follows, using an IECC/IRC-traceable DOE-2 simulation of a 2,000 to 2,500 ft<sup>2</sup> house with 18% window to floor area. The savings associated with this are estimated to be 1.3 kWh/yr-ft<sup>2</sup>, which is 2,607 to 3,259 kWh/yr-house, or 22.7 to 28.5 million MWh statewide. The potential NOx reduction is 17,552 to 21,940 tons-NOx/yr, or 96.4 to 120.5 tons-NOx/182day (See appendix for detailed calculations).

The cost associated with this is estimated to be \$1/ft<sup>2</sup>-glazing, which is the cost to upgrade to Low-E. This would amount to \$3.1 to \$3.9 billion statewide, or \$18,112 \$/ton-NOx-yr, which is \$99 \$/ton-NOx-182day.

<sup>13</sup> Energy efficiency is related to other features, such as insulation levels, and whether or not the refrigerator has an automatic ice maker.

#### 4.1.2.6 Example: Accelerate the Use of Renewable Energy Systems.

Renewable energy systems also offer a substantial opportunity for reducing NOx emissions in Texas. If solar thermal domestic hot water systems could be installed in 50% of the 5.4 million houses in the non-attainment and affected counties, then the following potential NOx reductions can be calculated. The cost of these systems is estimated for two systems: a system with two 4 ft x 8 ft panels and an 80 gallon storage tank, and a system with one 4 ft x 8 ft panel with a 40 gallon rooftop storage tank. The delivery of these systems is estimated to be 80 and 50% respectively<sup>14</sup>.

The estimated savings from installing solar thermal DHW systems in 50% of the 8.8 million Texas houses projected for 2003 is 29.1 to 74.5 million MMBtu/yr, or 3,640 to 9,319 tons-NOx/yr, which is 9.9 to 25.5 tons-NOx/day. The cost associated with this would be \$13.4 to \$21.2 billion, which results in \$227,426 to \$363,882 \$/ton-NOx-yr, or \$623 to \$997 \$/ton-NOx-10yr-day.

#### 4.1.2.7 Example: Eliminate Pilot Lights in Residential Appliances

A large number of houses in the non-attainment and affected counties have active pilot lights that burn throughout the year. Pilot lights are used on all natural gas appliances to ignite the main burner when there is a demand for heating, water heating, etc. Although the new TNRCC rule 117 limits the amount of NOx that can be produced by certain types of gas consuming appliances it does not specifically address pilot lights<sup>15</sup>.

Fortunately, in new furnaces, manufacturers have decided to replace pilot lights with hot surface ignition devices that ignite the gas with a surface heated to the ignition point using electricity. This has been added to home furnaces to meet the higher furnace efficiencies. Unfortunately, only a few manufacturers of natural gas fired domestic water heaters offer hot surface ignition.

Therefore, there are millions of pilot lights in Texas that could be replaced with hot surface igniters. The potential reductions that would result if one pilot light were replaced in 50 – 75% of the 8.8 million Texas are estimated to be 32.8 to 52.2 million MMBtu/yr, which is 4,109 to 6,527 tons-NOx/yr, or 11.3 to 17.9 tons-NOx/day. The cost associated with this is estimated to be \$170 to \$270 per house, or \$750 to \$1,788 million, which results in \$18,265 \$/ton-NOx-yr, or \$75 \$/ton-NOx-10yr-day.

#### 4.2 Work with the TNRCC, PUC and SECO to develop standardized methods for reporting NOx reductions, including adjustments to electricity savings needed for the EGRID program

In order for the Senate Bill 5 legislation to accomplish its intended objective of reducing summertime ozone to levels to acceptable EPA levels there must be cost-effective, accurate feedback to the policy decision-makers. Such feedback depends upon the accurate documentation of potential emissions reductions, which are based on engineering calculations that contain estimates of energy reductions from the implementation of energy conservation in new construction and retrofits to existing construction.

In order to accomplish this the following tasks must be accomplished: 1) Uniform procedures need to be developed for documenting voluntary emissions reductions, and 2) Uniform analysis methods need to be developed for accurately reporting NOx emissions reductions during peak summer days, including refinement of the EPA's E-GRID software, and the development of detailed hourly savings for use in the state's hourly photochemical modeling process.

<sup>14</sup> This 50 to 80% efficiency refers to the ability of the system to provide the total annual domestic water heating needs. Usually, these systems provide all the needs in the summer months, falling short of the needs in the winter months as the systems strain to provide heating during periods of lower incident solar radiation, and falling ambient temperatures.

<sup>15</sup> A telephone survey of water heater manufacturers revealed that most of the manufacturers were unaware of TNRCC's Rule 117 and the July 1<sup>st</sup>, 2002 implementation date. None of the manufacturers could say how they were going to comply with this ruling and/or if this required the elimination of the pilot light. Many of the manufacturers already have units in stock that can meet the low-NOx requirements of TNRCC's Rule 117, however many distributors do not have sufficient stock of the low-NOx units.

#### 4.2.1 Develop Uniform Certification Procedure for Documenting Voluntary Emissions Reductions

At the present time Senate Bill 5 has procedures for accounting for building-related energy conservation activities that are part of: 1) the PUC's Senate Bill 5 and Senate Bill 7 programs, 2) SECO's energy conservation efforts (i.e., state programs such as LoanSTAR and Rebuild America, and other programs in political subdivisions), 3) The Laboratory's reporting of the energy savings from the implementation of the 2000 IECC/IRC in residential and commercial buildings, which covers new construction and building retrofits that require permits<sup>16</sup>.

Unfortunately, Senate Bill 5 needs to develop procedures for accounting for emissions reductions from voluntary energy conservation activities in residences, schools, facilities of Higher Education, and commercial buildings. Since the emissions reductions from these measures are expected to be large, it is important that standard procedures be developed for accounting for these reductions so that the uncertainty in the estimated emissions reductions can be reduced.

There are several industry efforts that can be called upon to help with this task, namely, the measurement and verification procedures developed by the USDOE in the International Performance Measurement and Verification protocols (IPMVP 2001), and in ASHRAE Guideline 14P (ASHRAE 2002), which includes before-after, component isolation and calibrated simulation methods. In order for these methods to be cost effective it is recommended that different type of calculation methods, varying from low-cost monthly utility billing analysis methods to the more accurate hourly measurement and verification methods. Where possible real energy consumption data should be used to estimate emissions reductions, versus stipulated or deemed savings that are inexpensive to apply but can be inaccurate.

##### 4.2.1.1 Development of Standardized, Low-cost, Monthly Utility Billing Analysis Procedures for Documenting Voluntary Emissions Reductions

The measurement and verification procedures contained in the USDOE International Performance Measurement and Verification protocols (IPMVP 2001), and in ASHRAE Guideline 14P (ASHRAE 2002), represent the consensus methods that have resulted from many years of experience with measuring and verifying savings, as shown Table 2. Texas has played a major role in the development of the national M&V protocols, first through the ground-break success of the Texas LoanSTAR program, which developed many of the monthly, daily and hourly M&V methods, and then in 1998 with the publication of the Texas State Performance Contracting Guidelines.

One of the important contributions of the IPMVP and ASHRAE Guideline 14P is the development of standardized procedures for normalizing for weather dependencies. These standard procedures consist of specific regression methods that are applied to utility billing data to create a weather-normalized energy baseline for a facility. Energy conservation savings are then calculated by comparing the baseline energy use against the post-retrofit energy use. A graphical representation of several of the regression models developed by ASHRAE is shown in Figure 15. The engineering equations for calculating the baseline model are shown in Table 3.

For illustrative purposes, an example application of procedures to the monthly utility billing data from a residence in College Station, Texas is shown in Figure 16, which shows the data required to run the regression, and in Figure 17, which shows the resultant model and the confidence intervals from the regression. In Figure 16 it is interesting to note that daily weather are used with the monthly utility billing data. This is because the average billing period temperature must be calculated for each monthly utility bill for each customer. Likewise, differences in the billing period length must be normalized by expressing the energy use daily average use.

It is therefore recommended that the TNRCC use standard procedures, such as the linear and change-point linear routines outlined in ASHRAE Guideline 14P, for tracking changes in monthly utility use. Although it

<sup>16</sup> This also includes the installation of renewable energy systems, as specified in Section 403 of the 2000 IECC.

2000 - IPMVP-2000 Released, Jan 2001  
 1998 - Texas State Performance Contracting Guidelines  
 1997 - IPMVP (revised NEMVP)  
 1996 - FEMP Guidelines  
 1996 - NEMVP  
 1995 - ASHRAE Handbook - Ch. 37 "Bld Energy Monitoring"  
 1994 - PG&E Power Saving Partner "Blue Book"  
 1993 - NAESCO M&V Ver 1.3  
 1993 - New England AEE M&V Protocol  
 1992 - California CPUC M&V Protocol  
 1989 - Texas LoanSTAR Program  
 1988 - New Jersey M&V Protocols  
 1987 - USDOE funded ELCAP Program  
 1985 - First Utility Sponsored Large Scale Programs  
 1985 - ORNL's "Field Data Acq. For Bld & Eqp Energy Use Monitoring"  
 1983 - Intl Energy Agency "Guiding Principles for Measurement"  
 1970s - First Simulations on Mainframe

Table 2: History of M&V protocols 1970 to present.

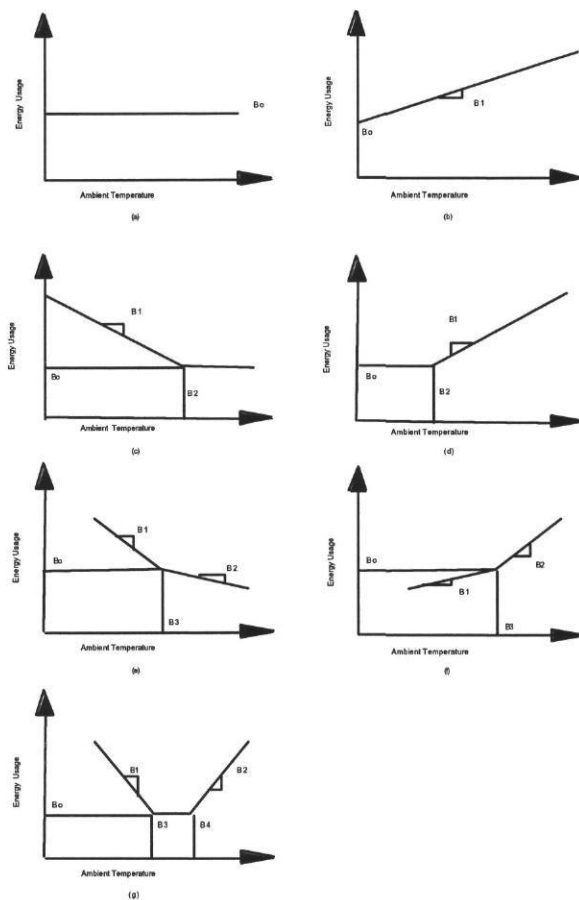


Figure 15: Linear and change-point linear models for weather normalization.

Name	Independent Variable(s)	Form	Examples
No Adjustment /Constant Model	None	$E = E_b$	Non weather sensitive demand
Day Adjusted Model	None	$E = E_b \times \text{day}_b$ $\text{Day}_b$	Non weather sensitive use (fuel in summer, electricity in summer)
Two Parameter Model	Temperature	$E = C + B(T)$	
Three Parameter Models	Degree days/Temperature	$E = C + B_1(DD_{BT})$ $E = C + B_1(B_2 - T)^+$ $E = C + B_1(T - B_2)^+$	Seasonal weather sensitive use (fuel in winter, electricity in summer for cooling) Seasonal weather sensitive demand
Four Parameter, Change Point Model	Temperature	$E = C + B_1(B_2 - T)^+ - B_2(T - B_3)^+$ $E = C - B_1(B_3 - T)^+ + B_2(T - B_3)^+$	
Five Parameter Models	Degree days/Temperature	$E = C - B_1(DD_{BT}) + B_2(DD_{TC})$ $E = C + B_1(B_3 - T)^+ + B_2(T - B_4)^+$	Heating and cooling supplied by same meter.
Multi-Variate Models	Degree days/Temperature, other independent variables	Combination form	Energy use dependent non-temperature based variables (occupancy, production, etc.).

Table 3: Linear and change-point linear models for weather normalization.

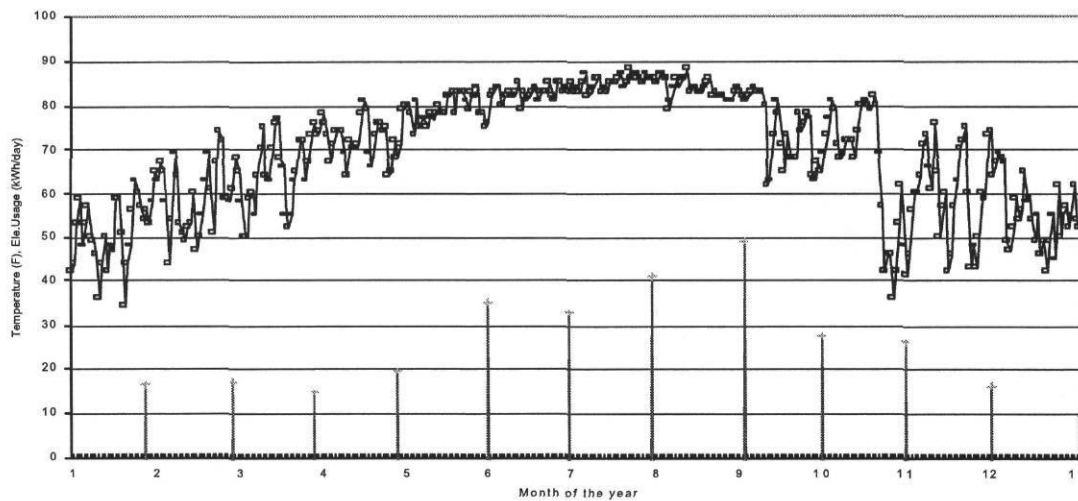


Figure 16: Example of data required for weather-normalized monthly utility bill analysis.

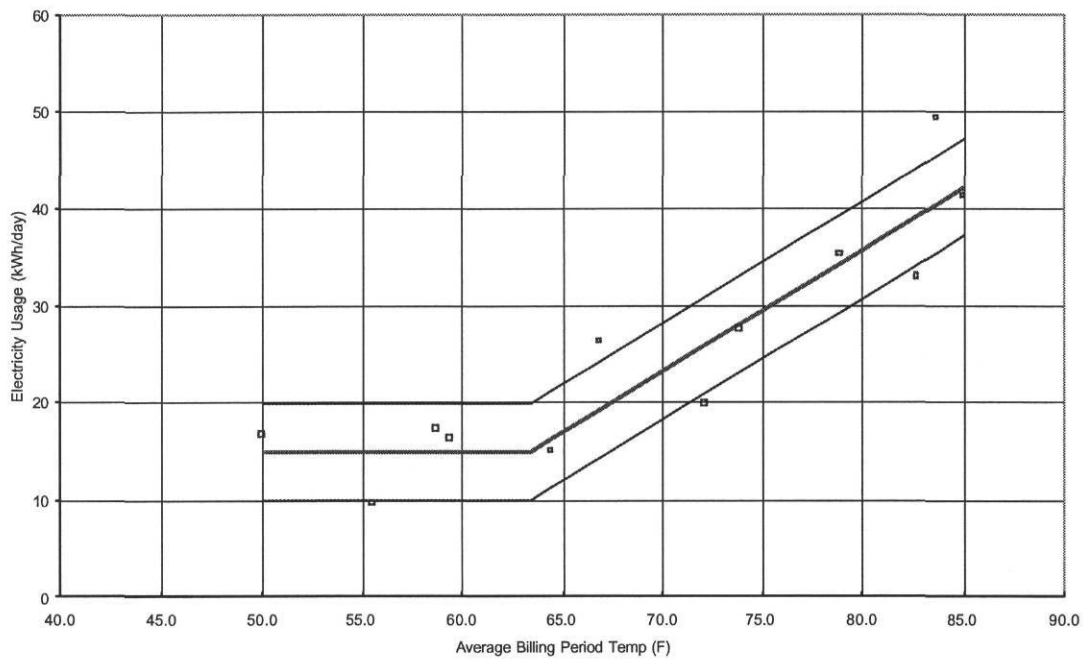


Figure 17: Example of three-parameter model for weather-normalized monthly utility bill analysis.

may not be cost effective to perform these procedures on every building and residence that is retrofitted, a statistically significant sampling of such procedures is recommended for use by all agencies participating in the Senate Bill 5 program (i.e., PUC, SECO and the Laboratory). Public domain routines<sup>17</sup>, including FORTRAN source code, for calculating these models are available from ASHRAE (Kissock et al. 2001).

#### 4.2.1.2 Development of Hourly Analysis Procedures for Documenting Voluntary Emissions Reductions

ASHRAE Guideline 14P also includes methods for weather-normalizing daily and hourly measured data. Such routines utilize the same linear and change-point linear models as the monthly methods, as well as additional methods that can be used for evaluating peak electric loads, such as the ASHRAE Diversity Factor calculations<sup>18</sup>, as well as component isolation methods for measuring the energy savings from specific equipment, such as boilers, and chillers.

Weather-independent hourly models. Several applications of these methods are provided in the next set of figures. For example, in Figure 18 and one year of whole-building electricity use is shown for the U.S.D.O.E. Forrestal building. It is clear in this figure that the electricity demand of this building varies daily from less than 1,500 MW to more than 4,500 MW, and as shown in the middle of the figure, there are periods in the summer when air-handling units are left running, which keeps the night-time electricity use higher than normal. To better understand the electricity use profile for this building a diversity profile was developed using the ASHRAE 1093-RP procedures as shown in Figure 19. Such profiles are useful for determining graphically, as well as statistically, how the building is performing, and can be used to capture the weather-independent baseline of the building for purposes of measuring hourly energy savings.

Weather-dependent hourly models. In contrast to weather-independent loads that can be modeled using a 24-hour weekday-weekend diversity profile, the hourly cooling data from several buildings is provided in the next several figures. The modeling of the hourly cooling loads, which can be important for determining summertime, hourly NOx reductions in large commercial buildings, is very dependent upon how the building is operated, and what type of cooling system the building has. For example, in Figure 20 the hourly before measured thermal loads are shown for the MSC building on the Texas A&M campus, where several Continuous Commissioning<sup>SM</sup> measures were applied to reduce the cooling load of the HVAC system. In this building it is clear to see that, during the summer of the pre-retrofit period, the building's cooling load reached an upper limit of capacity at about 75 F, and varied from 6 to 8 MMBtu/h. After the commissioning retrofit, the building's cooling load was reduced, as was the peak cooling load, which is evident by the fact that the post-retrofit data never reaches the same peak as the pre-retrofit data.

Such measured hourly data can be analyzed with the same methods used in the monthly analysis, and is often modeled best with daily data (i.e., derived from the hourly measurements), regressed against average daily temperatures, as shown in Figure 21, which shows before-after change-point linear regression of the Winship building on the University of Texas campus. Such daily before-after change-point linear models can be very useful for tracking the energy use of a building after a retrofit to determine if the building is continuing to be energy efficient, an important feature for reducing and then sustaining low energy use and the associated emissions.

Unfortunately, not all buildings are easily modeled with hourly or daily regression models. For example, in Figure 22 the cooling load is shown for a library in Toronto, Ontario, Canada, along with the coincident weather data. In this figure it is clear to see that the cooling load is influenced by the time of day and the hourly ambient temperature. However, when we plot the hourly cooling load versus hourly ambient temperature for the corresponding period, we see only a vague relationship with temperature, one which would be poorly modeled by a linear or change-point linear model. To better understand this building, one would need to develop component models, as well as hourly cooling loads models.

<sup>17</sup> These public domain routines were developed as part of ASHRAE Research Project 1050RP and are available as FORTRAN source code to stimulate wide-spread use.

<sup>18</sup> These diversity factor calculation procedures were developed as part of ASHRAE Research Project 1093-RP (Abushakra 2001).



An example of a component model used in ASHRAE Guideline 14P is shown in Figure 24, which shows the variation in the efficiency of the chiller versus the chiller load. In this figure the actual data and the tri-quadratic chiller model are shown that accurately captures the performance of the chiller, despite variations in load, chilled water supply temperature, and condenser water return temperature.

To summarize, it is recommended that the TNRCC adopt standard procedures, such as those outlined in ASHRAE Guideline 14P, for measuring the energy avoidance in new construction, and the voluntary energy reductions in existing buildings. Such procedures can vary from inexpensive monthly utility billing analysis regression models, to the more complex, and more accurate hourly component models, such the chiller performance models. The development and application of such procedures will reduce the uncertainty of the calculation of energy savings, and the associated emissions reductions. Such procedures will also pave the way for the development of emissions trading efforts that can accelerate energy reductions by delivering incentive mechanisms for private capitol investment, as well as the proper, standardized accounting procedures to make sure savings are occurring as predicted by the engineers that designed the retrofits, and that savings continue to occur into the future, as necessary for long-term emissions reduction.

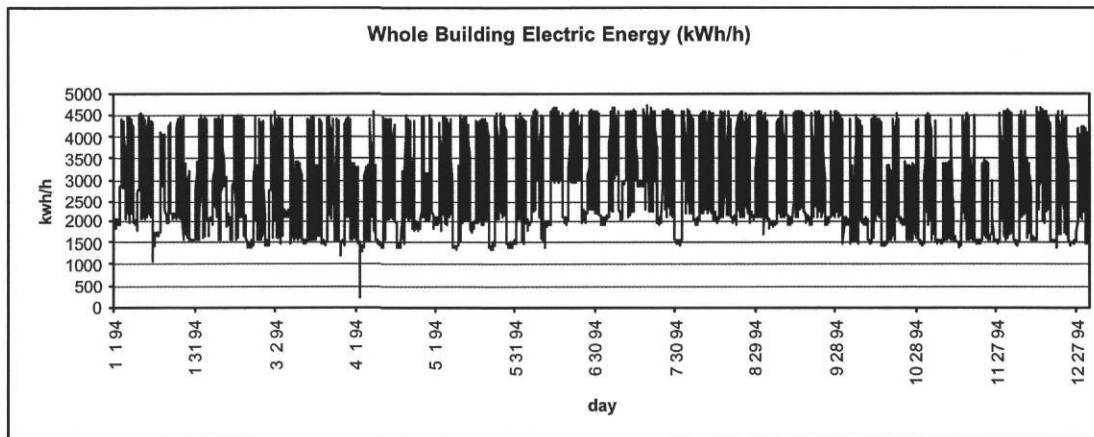


Figure 18: Example of one year of hourly whole-building electricity use (U.S.D.O.E. Forrestal Building).

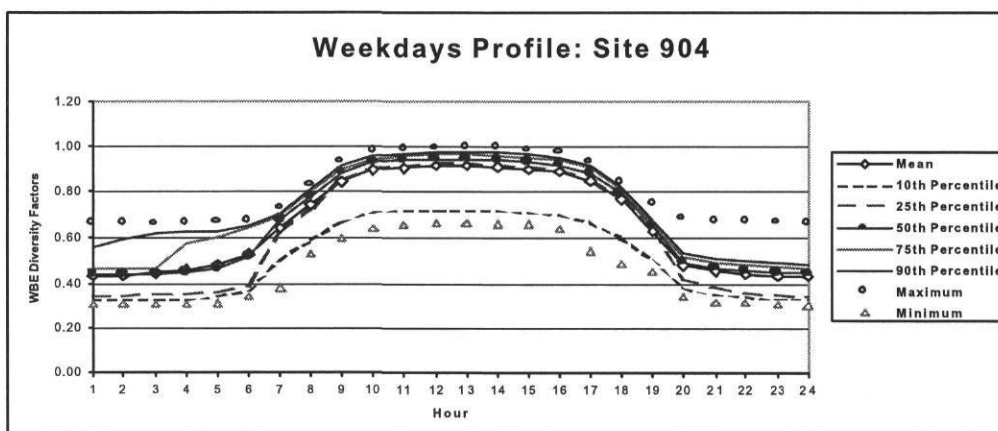


Figure 19: Example of 24-hour daytype profile from hourly whole-building electricity use (U.S.D.O.E. Forrestal Building).

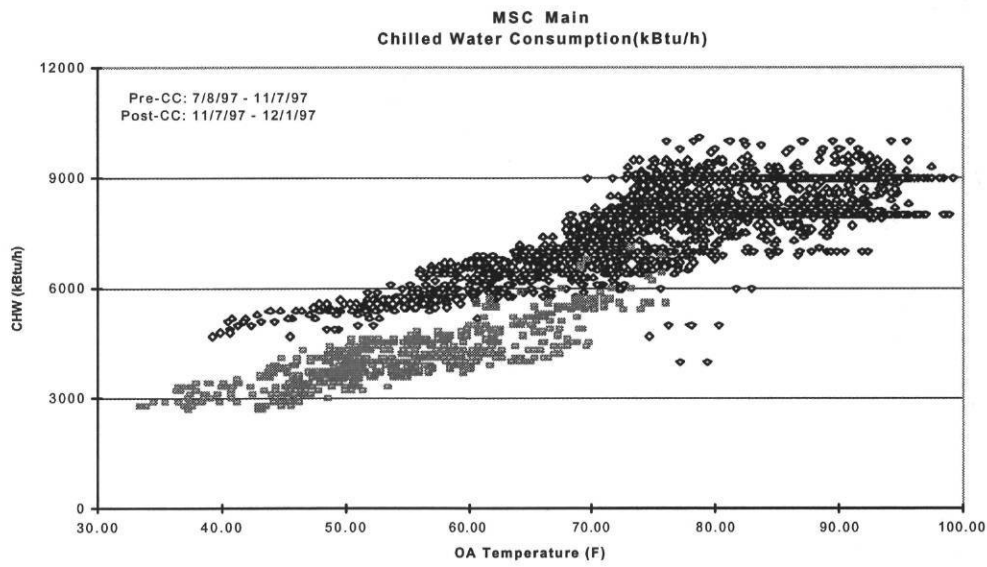


Figure 20: Example of before-after hourly chilled-water use (MSC building).

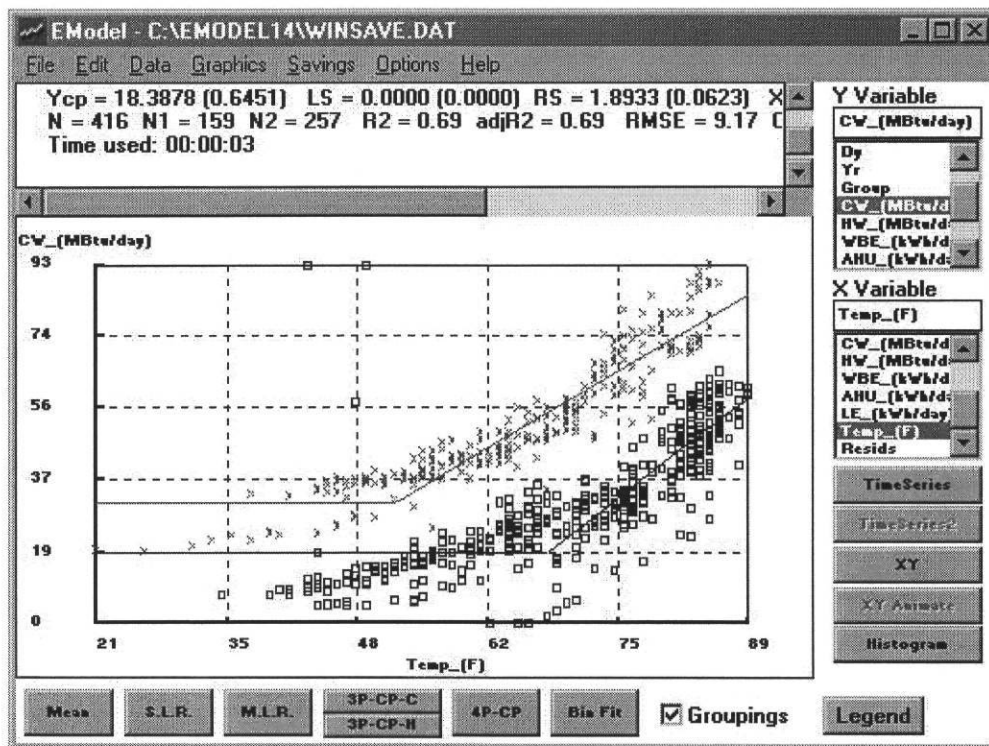


Figure 21: Emodel software developed as part of the LoanSTAR program used to model the Winship building on the University of Texas campus.

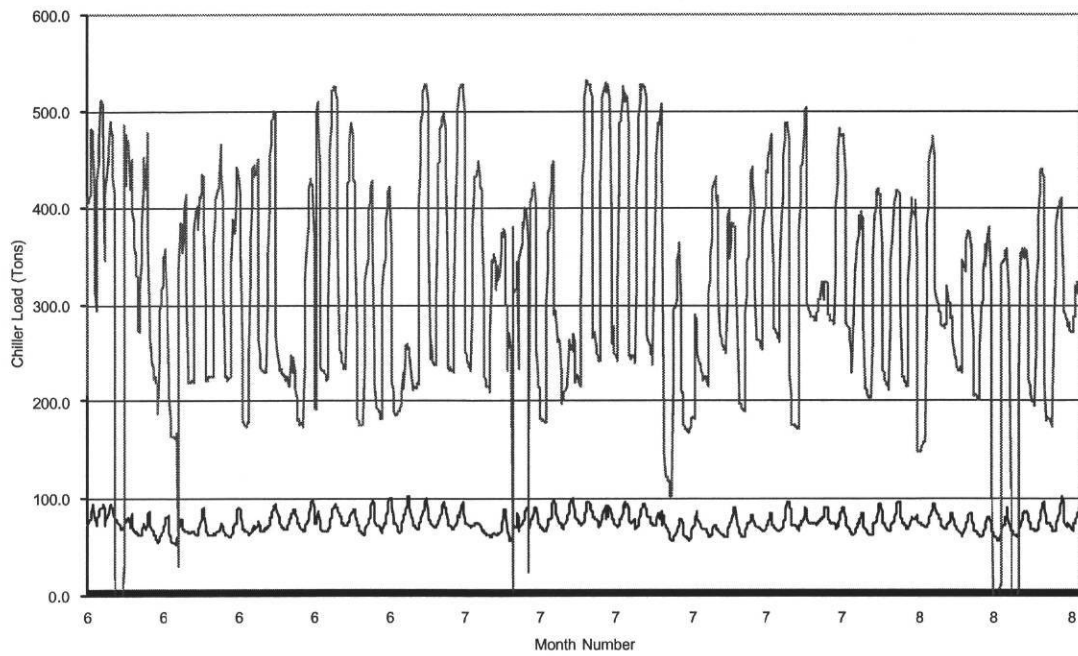


Figure 22: Example of hourly cooling load and ambient temperature data from a library in Toronto, Ontario, Canada.

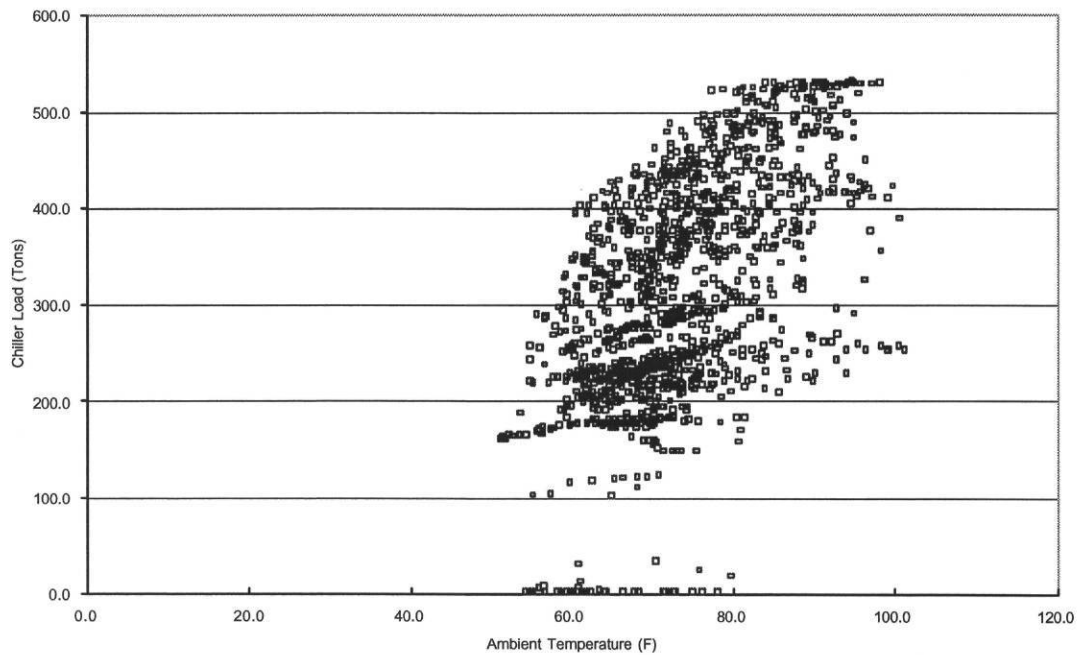


Figure 23: Example of hourly cooling load versus ambient temperature data from a library in Toronto, Ontario, Canada.

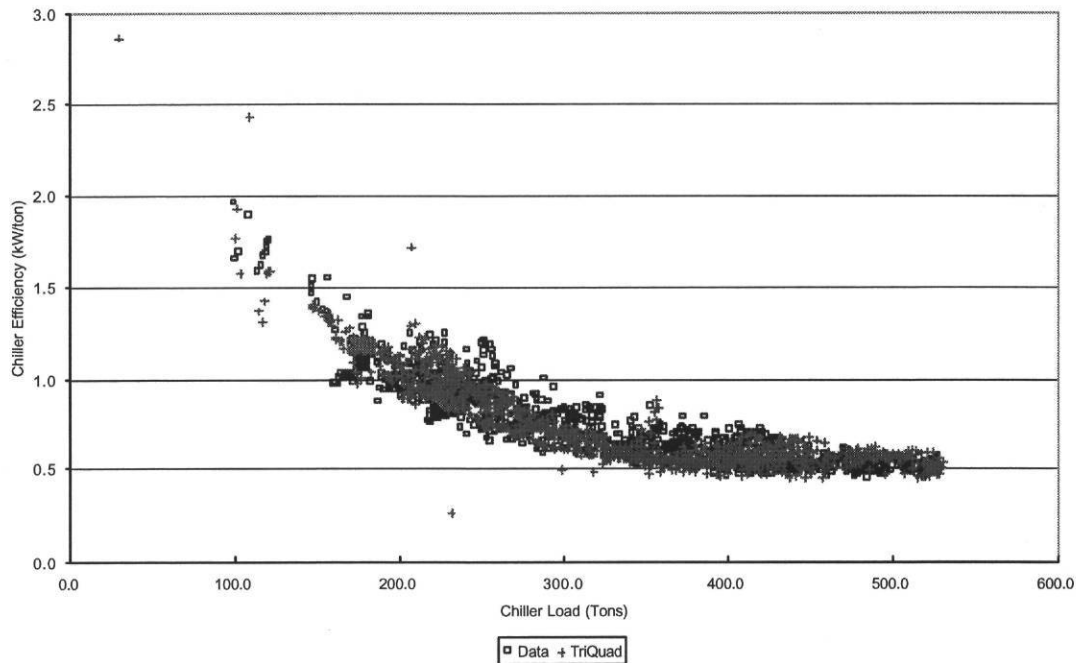


Figure 24: Example of hourly performance profile for the chillers in the library in Toronto, Ontario, Canada.

#### 4.2.2 Refinement of the Analysis Method for Reporting Emissions Reductions.

As we go forward, improved emissions reporting methods will need to be developed that provide greater accuracy in estimating ozone reductions from electricity reductions in buildings. The Laboratory can determine the energy reductions in the municipalities and counties using a variety of methods. Ideally, we would like to have a “1-sheet” list of key code parameters on each building with its location. We will have the computer systems in place to then determine the location and quantify the energy reductions. Next, this hourly energy reduction profile needs to be tied to a particular power plant, which has specific operating conditions on NO<sub>x</sub> emissions. ERCOT data, grid models and dispatch models will be required for this. Finally, the reduction of hourly NO<sub>x</sub> output of the power plant needs to be put into an acceptable hourly atmospheric model (i.e., Ozone day or August-September 2000 Episode day) to determine the reduction in ozone. Although this description is overly-simplified, four groups must work closely together to accomplish this task. These are the Laboratory, TNRCC, ERCOT and the UT Atmospheric Sciences Group. This group can put a solid, defensible set of ozone reductions forward to the US EPA. The legislature could address how to allow these data to be acquired as truly needed. Deregulation of the electric utilities is also complicating the acquisition of needed data.

#### 4.3 Other Recommendations

##### 4.3.1 Refinement of the Analysis Method for Reporting Costs Associated With Building to Code Standards.

Additional work needs to be done in quantifying and demonstrating the cost associated with building to code standards. Cost will increase due to added insulation, higher efficiency windows, higher efficiency air-conditioners and other added items. Cost will decrease due to being able to down-size air-conditioners and furnaces and some other potential design changes like high efficiency ducts. Also, energy bills will

decrease. “Back of the envelop” calculations show that the initial cost increase can be \$1,000 to \$2,000 or so, depending on what is done. A payback of under 3 to 5 years should be expected. Technologies are being developed to enable the first cost to be less than the old building methods, allow better comfort and improved energy efficiency. The Laboratory needs to participate in developing, demonstrating and training builders in these technologies and methods.

#### 4.3.2 Study methods to reduce NOx emissions from energy use in new and existing residential, commercial and industrial buildings.

Currently, Senate Bill 5 seeks to reduce the energy used in buildings through the implementation of a statewide energy code. Although this approach is proving to be effective, there are still a number of issues that need to be resolved regarding the reduction of NOx emissions. For example, in the 2000 IECC/IRC, a building is said to comply with the code if the annual energy use is at or below the annual energy use of a similar building that is built to the prescriptive code requirements. A building can therefore be evaluated by looking at individual, prescriptive measures, or the performance of the building can be compared *relative* to the performance of a similar building that has a similar shape and energy consuming systems.

Unfortunately, to evaluate the NOx emissions one needs to perform an *absolute* energy performance, where one calculates the NOx emissions from all energy that is consumed by the building— regardless of the type of energy consuming system, or shape of the house. This would then allow for the NOx emissions of house that has a gas furnace, a gas domestic water heater, and an electric air conditioner to be compared to the NOx emissions of an all electric house.

## 5 TECHNOLOGY OF REPORTING & VERIFYING EMISSIONS REDUCTIONS FROM ENERGY USED IN BUILDINGS

Senate Bill 5 will allow the TNRCC to obtain emissions reduction credits for reductions in electricity use and electric demand that are attributable to the adoption of the International Energy Conservation Code (IECC 2000) in non-attainment and affected counties. In order for the TNRCC to accomplish this, county-wide reductions in electricity use will be calculated by the Laboratory and presented to the TNRCC in a suitable format for calculating emissions reductions. Ultimately, the format and procedures for calculating emission savings must be approved by the EPA<sup>19</sup>.

In this report two types of calculation procedures are discussed in regards to the estimation of emissions reductions from buildings: data requirements for the calculation of annual NO<sub>x</sub> reductions, and data requirements for hourly ozone modeling.

### 5.1 Procedures for Calculating Electricity Reductions

#### 5.1.1 Residential Buildings

The methodology to accomplish this for residential buildings is presented in Figure 26 - Figure 30. This methodology is composed of several procedures that will calculate and verify savings using several different sources of information. These procedures include:

1. The calculation of electricity savings and peak demand reductions from the implementation of the IECC 2001 (Figure 25) in new residences in non-attainment and affected counties as compared against 1999 housing characteristics (IECC 2001 residential emissions reductions) using calibrated simulation.
2. A cross-check of the calculated energy use<sup>20</sup> against the published average energy use found in the USDOE's Residential Energy Characteristics Survey (RECS 1999)
3. A cross-check of electricity savings using a utility bill analysis method.
4. A cross-check of construction data using on-site visits.

##### 5.1.1.1 Residential: New Construction

Calculation of the Potential for Emissions Reductions. The primary procedure for calculating the emissions reductions from the adoption of the IECC 2001 in new residences is shown in Figure 26 and Figure 27. Figure 26 is a flowchart of the overall procedure, which includes the information obtained from Figure 27. For each county, 1999 and 2002 residential housing characteristics will be ascertained according to the procedures in Figure 27. Using simulation, these characteristics are entered into the DOE-2 simulation to calculate the annual energy use of two average-sized residences, one representing the house with the average 1999 characteristics, and one representing the appropriate characteristics from the 2001 IECC. The annual electricity use of the 2001 IECC simulation is then subtracted from the annual electricity use of the similarly-sized 1999 residence to obtain the annual electricity savings, and peak electric demand savings. Natural gas savings associated with space heating and the heating of domestic hot water would be calculated for informative purposes. The electricity savings attributable to the 2001 IECC energy conservation options would then be converted to NO<sub>x</sub> reductions per house using the appropriate state-wide, utility grid conversion model. Electricity savings would then be scaled to represent the county-wide

<sup>19</sup> Additional information can be found in the TNRCC document "Conceptual Model for Ozone Formulation in the Houston-Galveston Area: Appendix A to Technical Support Document - Conceptual Model for Ozone Formulation", June 5, 2002.

<sup>20</sup> This energy use reported by RECS represents the total energy use, which would include electricity use and natural gas use.

savings by multiplying the annual residential building permits for each county. Total annual NO<sub>x</sub> reductions associated with the implementation of the 2001 IECC would then be calculated simultaneously for all non-attainment and affected counties using a state-wide conversion model.

In Figure 27 the detailed flowchart is shown for calculating the 2002 annual energy use of new residential construction for houses with and without the energy conserving features contained in the IECC 2001, chapters 4 and 6. This is accomplished with two separate calculations: a) one path that represents the standard house defined in the 2001 IECC chapter 4 and 5, that uses average housing characteristics for houses built in 1999 (left side of figure); and b) a second path that represents the standard house defined by the 2001 IECC that includes the energy conserving features<sup>21</sup> defined in chapter 4, 5 and 6 (right side of figure).

Calculating baseline energy use of new construction. The procedure for calculating the 2002 baseline residential energy consumption (left side of Figure 27) begins with the definitions of the standard house found in Chapter 4 of the 2001 IECC. These definitions are used to create a standard input file for the DOE-2 simulation program (LBNL 2000). This standard input file is then adjusted to reflect the average 1999 construction characteristics for each county<sup>22</sup> for type A-1 (single family) and type A-2 (all others) housing. The annual electricity and natural gas consumption for the average house<sup>23</sup> is then simulated using the DOE-2 program and the appropriate weather data<sup>24</sup> for each location. The annual, countywide, baseline energy consumption for new houses built in 2002 with characteristics that reflect the 2001 IECC and 1999 published data is calculated by multiplying the annual simulated energy use for an average house times the projected A-1 and A-2 county-wide housing permits for 2002. The projected A-1 and A-2 housing permits for each county are projected using multiple linear regression that utilizes countywide population growth and housing permits as shown in Figure 27. This baseline represents the expected annual energy use of all new construction in each county had those houses been constructed with the 2001 IECC chapter 4 and 5 “standard house” and average 1999 characteristics.

Calculating code-compliant energy use of new construction. The procedure for calculating the code-compliant 2002 residential energy consumption (right side of Figure 27) also begins with the definitions of the standard house found in Chapter 4 and 5 of the 2001 IECC. This code-compliant input file reflects the average 1999 house size<sup>25</sup> for each county and IECC Chapter 5 or 6 construction characteristics<sup>26</sup> for type A-1 (single family) and type A-2 (all others) housing. The annual electricity and natural gas consumption for a code-compliant house is then simulated using the DOE-2 program and the appropriate weather data for each location. The annual, countywide, code-compliant energy consumption for new houses built in 2002 with code-compliant characteristics is calculated by multiplying the annual simulated energy use for a code-complaint house times the projected A-1 and A-2 housing permits for 2002. This code-compliant use represents the expected annual energy use of all new code-complaint construction in each county. The total electricity savings which can be attributed to the adoption of the IECC 2001 are then calculated by comparing the difference in annual energy use of the baseline housing versus the code-compliant housing as shown in Figure 26.

#### Reconciliation of the Total Savings.

Several procedures have been identified to reconcile the savings calculations, including:

- a) a cross-check of the calculated energy use against the published average energy use found in the USDOE’s Residential Energy Characteristics Survey (RECS 1999) as shown in Figure 28;
  - b) a cross-check of energy savings using a utility bill analysis method as shown in Figure 29;
- and

<sup>21</sup> The energy conserving features in the IECC 2001 are the same as those contained in chapter 11 of the 2000 IRC, as modified by the 2001 Supplement (IECC 2001).

<sup>22</sup> The average 1999 construction characteristics represent the published data from several sources, including NAHB (2002), F.W. Dodge (2002), RECS (1999) and LBNL (1995).

<sup>23</sup> The average house size for each county is determined from published RECS (1995) data.

<sup>24</sup> The appropriate weather data for each county is the nearest TMY2 weather file that most accurately represents the 2001 IECC climate zone as shown in Figure 2.

<sup>25</sup> Uses the same average house size for each county as determined from published RECS (1995) data.

<sup>26</sup> These characteristics include insulation levels, glazing type, etc., as defined in Chapter 6 of the 2001 IECC or Chapter 11 of the 2001 IRC.



- c) a cross-check of construction data using on-site visits as shown in Figure 30.

Cross-check of the calculated energy use against published data. The procedure to cross-check the calculated energy use of the baseline houses and code-compliant houses against the average energy use published by the RECS (1999) is shown in Figure 28. It is important to note that this procedure is proposed for informative purposes, since exact agreement between the housing characteristics in the IECC 2001 and RECS is not anticipated, since the RECS data reflects actual average occupant behavior, and the IECC reflects a controlled occupant behavior. The procedure multiplies the expected number of A-1 and A-2 housing units times the average annual energy use per household published in RECS to obtain the county-wide annual energy use for all newly constructed houses. This value is expected to be useful in judging whether or not any adjustments are needed in the 2001 IECC Chapter 4 and 5 construction characteristics.

Cross-check of energy savings using utility bill analysis. The energy savings attributable to the adoption of the 2001 IECC will be reconciled with monthly utility billing data using the well-known Princeton Scorekeeping Method (PRISM) (Fels 1986; Fels et al. 1995) as shown in Figure 29. In general, the difference between average 1999 and 2002 utility bills should decrease by an amount that is similar to the calculated savings from 2001 IECC adoption for similar sized houses, with equal numbers of occupants, in similar neighborhoods. In Figure 29 the procedure for accomplishing this is set forth. The procedure has two parallel paths, one for the 1999 housing stock (left side of Figure 29) and one for the 2002 housing stock (right side of Figure 29).

For the housing cross-check with utility billing data, the procedure begins by selecting a 1999 house and a 2002 house that have similar characteristics to the construction characteristics that were used for the primary calculation shown in Figure 26 and Figure 27. For each house 12 months of utility billing data are obtained and analyzed with PRISM. The resultant, valid parameters from PRISM<sup>27</sup> are then normalized by conditioned area to obtain a weather-normalized, averaged energy use per square foot. After the appropriate number of houses have been analyzed that represent a statistically significant sample of houses constructed in 1999 for each county (or for 2002), the Normalized Annual Consumption (i.e.,  $NAC_{1999}$  expressed as  $kWh/yr-ft^2$ ) is compared against the similar parameter for houses constructed in 2002 (i.e.,  $NAC_{2002}$  expressed as  $kWh/yr-ft^2$ ) to obtain the average electricity savings per square foot of conditioned area. This difference is then multiplied by the number of houses constructed in 2002 and the average conditioned area of the houses constructed in 2002 to obtain the total annual electricity savings per county. This total, county-wide, annual electricity savings calculated by utility bill analysis can then be compared to the total, county-wide, annual electricity savings calculated by simulation (i.e., Figure 26 and Figure 27). For each county, savings from the difference in 1999 versus 2002 utility bills are expected to be similar to savings calculated by simulation for similar houses, with similar household characteristics<sup>28</sup>.

Cross-check of construction data using on-site visits. A reconciliation will also be carried out to cross-check selected parameters for both the 1999 and 2002 housing characteristics for each county as shown in Figure 30. For the 1999 housing stock, on-site surveys of a statistically significant sample will be used to cross-check the average building characteristics<sup>29</sup> used to simulate the average house in each county. Adjustments can then be made to the average 1999 characteristics should significant differences be found.

As shown in the right side of Figure 30, a similar procedure will be carried out for houses constructed in 2002 to determine if the on-site housing characteristics meet, or exceed the 2001 IECC. However, differences found in the 2002 characteristics will be noted as to whether or not these differences represent characteristics that are less stringent or more stringent than code. Characteristics that are less stringent than code will be communicated with code officials to determine how procedures to the code need to be modified to better meet code requirements. Characteristics that are more stringent than code will be credited to the countywide energy savings as above code savings.

<sup>27</sup> The primary parameter of interest from the PRISM analysis is the Normalized Annual Consumption (NAC). The goodness of fit indicators used to determine a valid PRISM run include the CV(NAC), and PRISM's adjusted  $R^2$ .

<sup>28</sup> If necessary, a similar procedure can be used to cross-check heating savings with either a 5 parameter change-point model using monthly electricity utility bills, or a PRISM model applied to monthly natural gas utility bills.

<sup>29</sup> As previously mentioned the 1999 average building characteristics represent the average characteristics published by NAHB, F.W. Dodge and LBNL.

#### 5.1.1.2 Residential: Existing Construction

Existing residential buildings that undergo a significant remodeling are addressed by the 2000 IECC/IRC. To account for the energy savings from these activities, procedures would be similar to those for new construction that track remodeling permits, including how the buildings are complying with the 2000 IECC/IRC. Different procedures may need to be developed for tracking existing building 2000 IECC/IRC activities. For example, it may be more efficient to track the activity by the type of retrofit, including: envelope, HVAC system, etc. Once a tracking procedure has been developed, then a suitable accounting scheme can be developed and implemented to include these savings in with the savings from new construction activities.

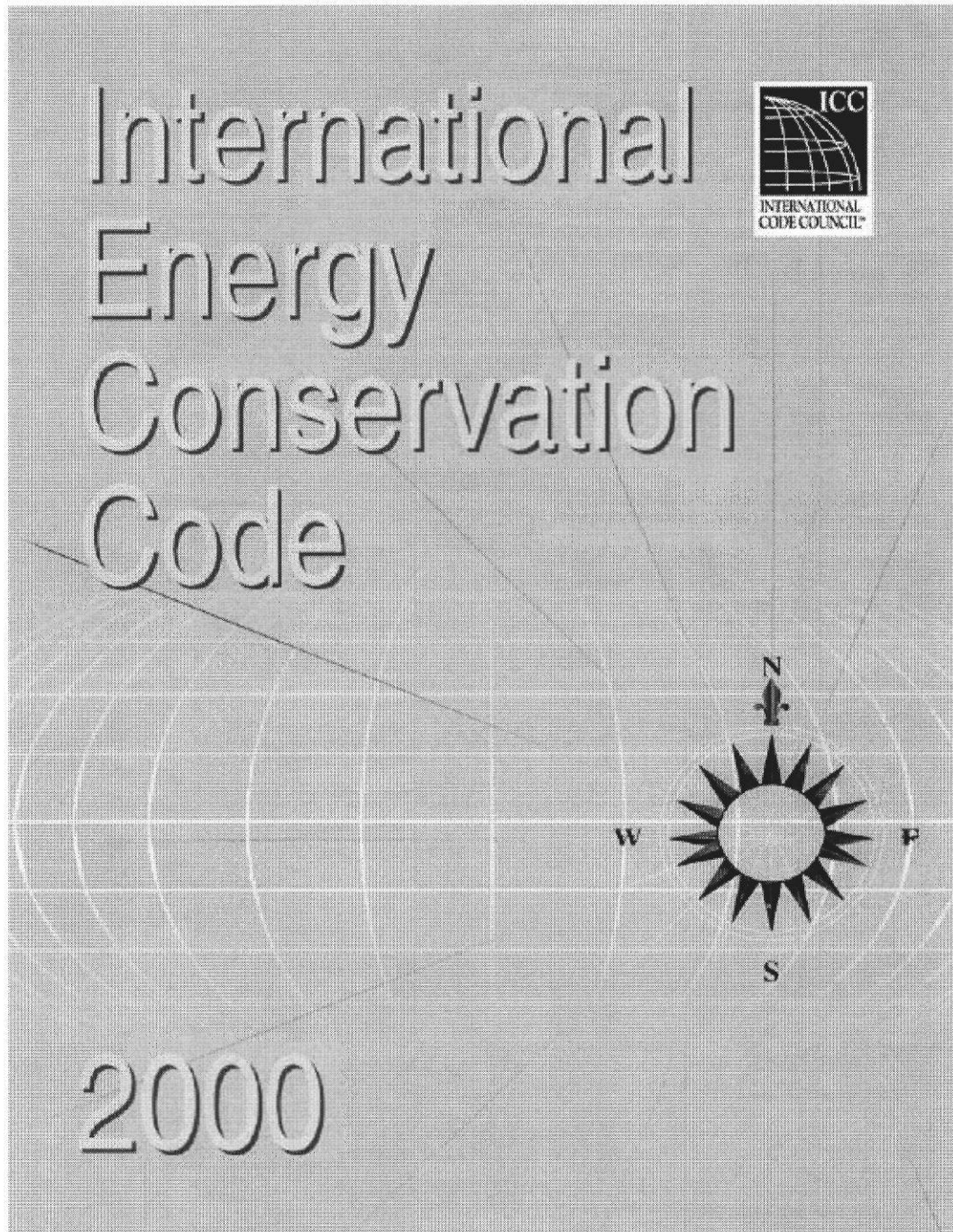


Figure 25: 2000 International Energy Conservation Code (IECC).

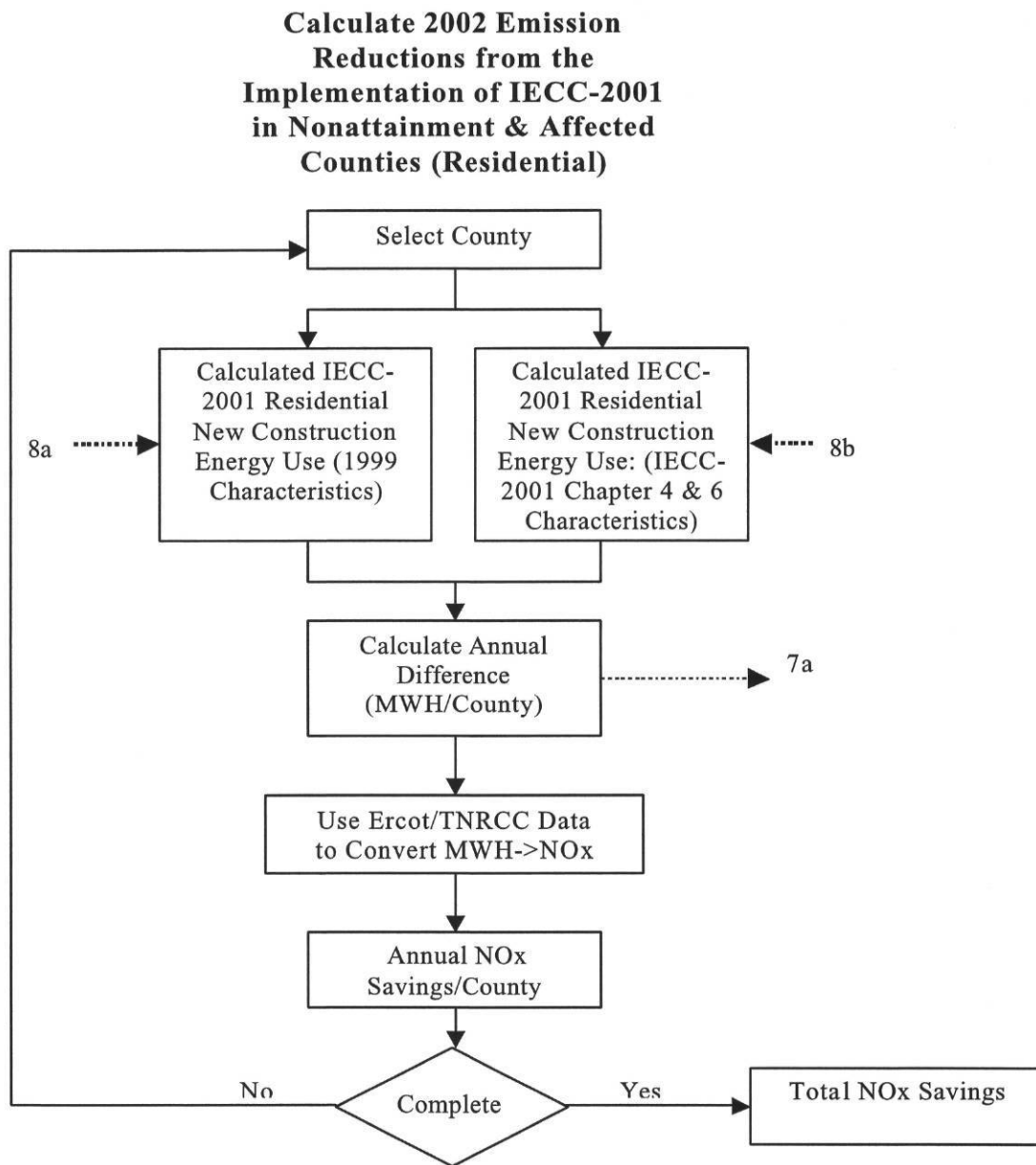


Figure 26: Overall flowchart for calculation of emission reductions from implementation of IECC/IRC 2001 in residential construction in non-attainment and affected counties.

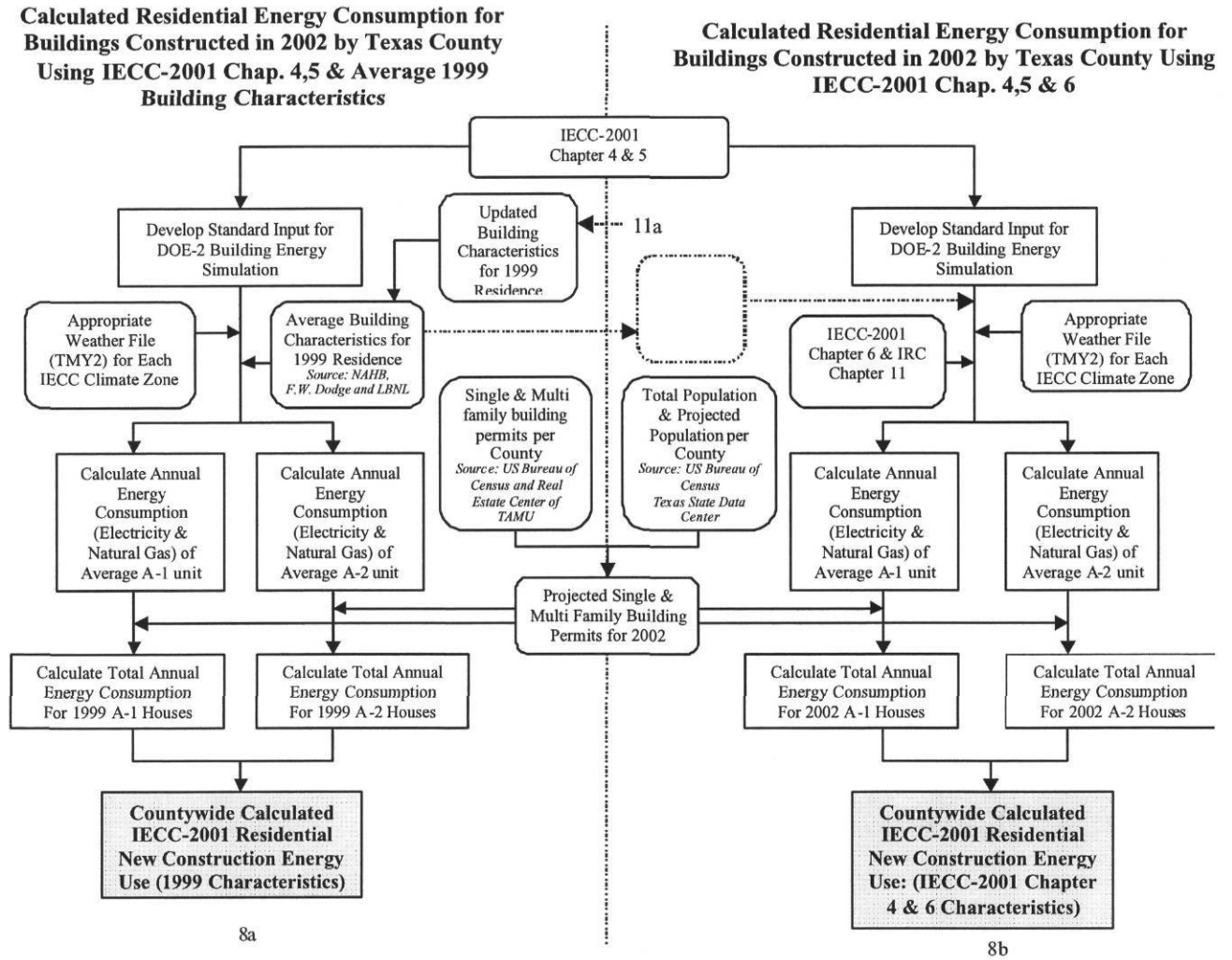


Figure 27: Calculation of countywide residential new construction energy consumption (1999 characteristics and 2001 IECC/IRC).

## Estimated Residential Energy Consumption for Buildings Constructed in 1999 by Texas County

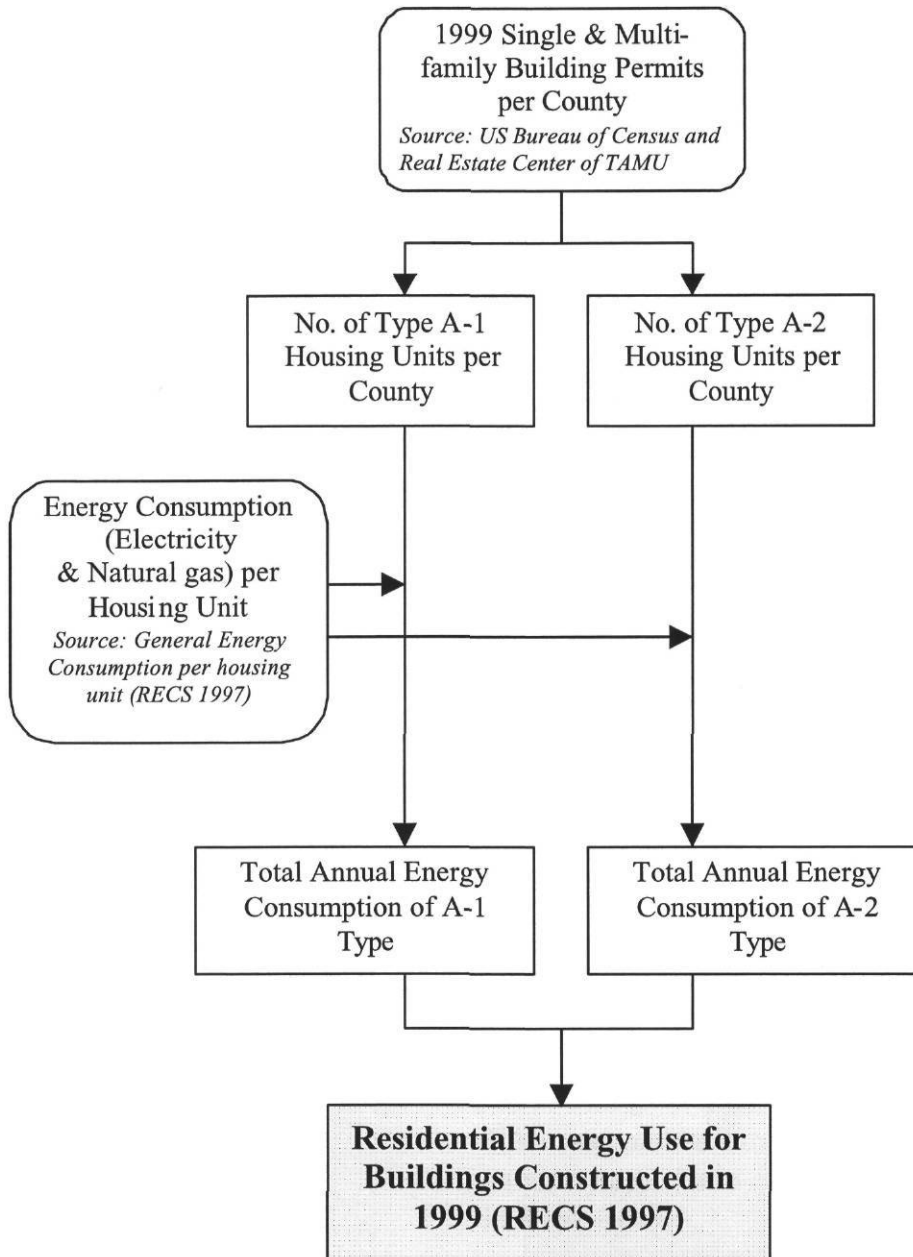


Figure 28: Estimated residential energy consumption for buildings constructed in 1999 by Texas county.

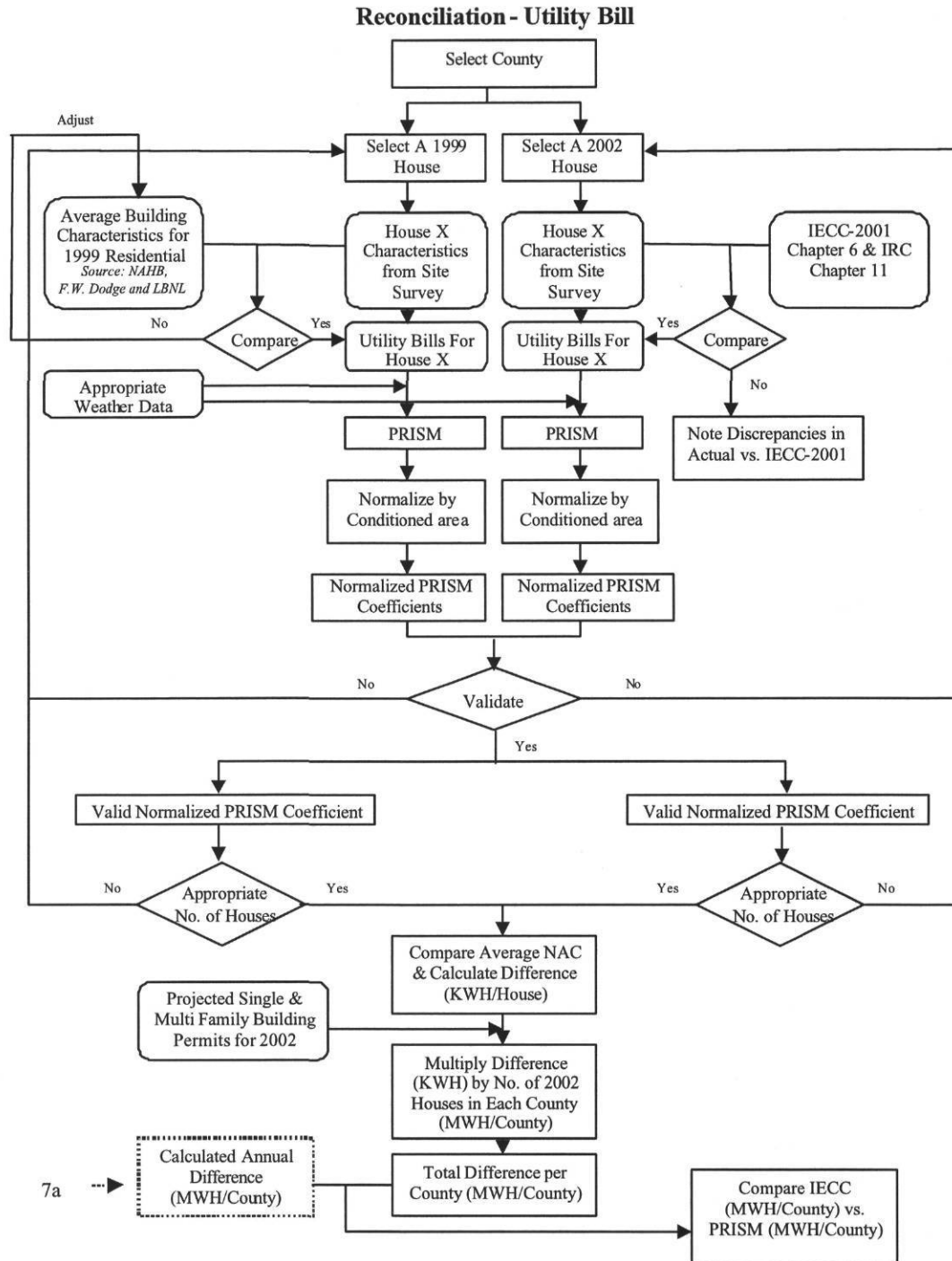


Figure 29: Reconciliation of residential energy savings using utility bill analysis.



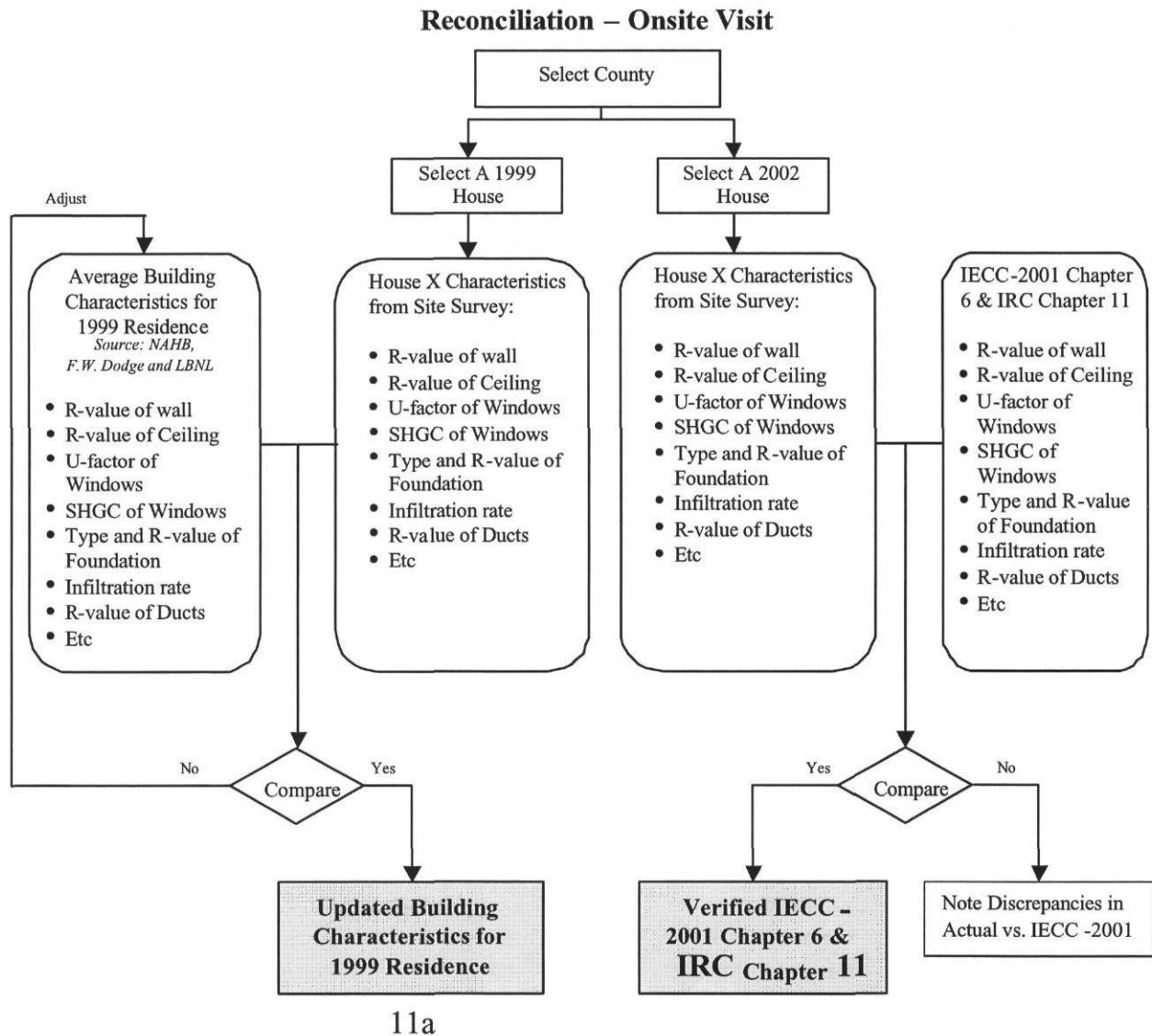


Figure 30: Reconciliation residential housing characteristics using on-site surveys.

### 5.1.2 Commercial/Industrial Buildings

The methodology to accomplish this for commercial buildings is presented in Figure 31 through Figure 35. These procedures incorporate and verify savings using several different sources of information. These procedures include a flowchart of the overall procedure, which includes the information obtained from Figure 32. For each county, 1999 and 2002 commercial building characteristics will be ascertained according to the procedures in Figure 32. Using simulation, these characteristics are entered into the DOE-2 simulation to calculate the annual energy use of two representative buildings, one representing the commercial building with the average 1999 characteristics, and one representing the appropriate characteristics from the 2001 IECC. The annual electricity use of the 2001 IECC simulation is then subtracted from the annual electricity use of the similarly-sized 1999 building to obtain the annual electricity savings, and peak electric demand savings. Natural gas savings associated with space heating and the heating of domestic hot water would be calculated for informative purposes. The electricity savings attributable to the 2001 IECC energy conservation options would then be converted to NO<sub>x</sub> reductions per building using the appropriate state-wide, utility grid conversion model. Electricity savings would then be scaled to represent the county-wide savings by multiplying the annual commercial building permits for each county. Total NO<sub>x</sub> reductions associated with the implementation of the 2001 IECC would then be calculated simultaneously for all non-attainment and affected counties using a state-wide conversion model.

In Figure 32 the detailed flowchart is shown for calculating the 2002 annual energy use of new commercial building construction with and without the energy conserving features contained in the IECC 2001, chapters 4, and 8. This is accomplished with two separate calculations: a) one path that represents the standard building defined in the 2001 IECC chapter 4 and 8, that uses average characteristics for buildings built in 1999 (left side of figure); and b) a second path that represents the standard building defined by the 2001 IECC that includes the energy conserving features<sup>30</sup> defined in chapter 7 and 8 (right side of figure).

Calculating baseline energy use of new construction. The procedure for calculating the 2002 baseline commercial building energy consumption (left side of Figure 32) begins with the definitions of the standard building found in Chapters 4 and 8 of the 2001 IECC. These definitions are used to create a standard input file for the DOE-2 simulation program (LBNL 2000). This standard input file is then adjusted to reflect the average 1999 construction characteristics for each county<sup>31</sup> for office, retail and industrial buildings. The annual electricity and natural gas consumption for each building type<sup>32</sup> is then simulated using the DOE-2 program and the appropriate weather data<sup>33</sup> for each location. The annual, countywide, baseline energy consumption for new buildings built in 2002 with characteristics that reflect the 2001 IECC and 1999 published data is calculated by multiplying the annual simulated energy use for an average building times the projected county-wide construction permits for 2002. The projected office, retail and industrial construction permits for each county are projected using regression that utilizes countywide population growth and construction permits. This baseline represents the expected annual energy use of all new construction in each county had those buildings been constructed with the 2001 IECC chapter 4 and 8 “standard building” and average 1999 characteristics.

Calculating code-compliant energy use of new construction. The procedure for calculating the code-compliant 2002 commercial building energy consumption (right side of Figure 32) also begins with the definitions of the standard building found in Chapter 4 and 8 of the 2001 IECC. This code-compliant input file reflects the 1999 floor area<sup>34</sup> for office, retail, industrial permits in each county and IECC Chapter 7 or

<sup>30</sup> The energy conserving features in the IECC 2001 are those contained in chapter 8 of the 2000 IRC, as modified by the 2001 Supplement (IECC 2001).

<sup>31</sup> The average 1999 construction characteristics represent the published data from several sources, including F.W. Dodge (2002), CBECS (1995) and LBNL (1995).

<sup>32</sup> The average building size for each county is determined from published CBECS (1995) data.

<sup>33</sup> The appropriate weather data for each county is the nearest TMY2 weather file that most accurately represents the 2001 IECC climate zone as shown in Figure 2.

<sup>34</sup> This is derived from the published county-wide construction permit data on file with the Real Estate Center at Texas A&M University, also cross-checked with CBECS (1995) data.

8 construction characteristics<sup>35</sup>. The annual electricity and natural gas consumption for a code-compliant building is then simulated using the DOE-2 program and the appropriate weather data for each location. The annual, county-wide, code-compliant energy consumption for new buildings built in 2002 with code-compliant characteristics is calculated by multiplying the annual simulated energy use for a code-complaint buildings times the projected building permits for 2002. This code-compliant use represents the expected annual energy use of all new code-complaint construction in each county. The total electricity savings that can be attributed to the adoption of the IECC 2001 are then calculated by comparing the difference in annual energy use of the baseline building versus the code-compliant building as shown in

#### Reconciliation of the total savings.

Several procedures have been identified to reconcile the savings calculations, including:

1. a cross-check of the calculated energy use against the published average energy use found in the USDOE's Commercial Building Energy Characteristics Survey (CBECS 1995),
2. a cross-check of energy savings using a utility bill analysis method, and
3. a cross-check of construction data using on-site visits.

Cross-check of the calculated energy use against published data. The procedure to cross-check the calculated energy use of the baseline building and code-compliant building against the average energy use published by the CBECS (1995) as shown in Figure 33. It is important to note that this procedure is proposed for informative purposes, since exact agreement between the office, retail and industrial characteristics in the IECC 2001 and CBECS is not anticipated, since the CBECS data reflects actual average occupant behavior, and the IECC reflects a controlled occupant behavior. The procedure multiplies the expected number of office, retail and industrial building area times the average annual energy use per unit area published in CBECS to obtain the county-wide annual energy use for all newly constructed buildings. This value is expected to be useful in judging whether or not any adjustments are needed in the 2001 IECC Chapter 4, 7 and 8 construction characteristics.

Cross-check of energy savings using utility bill analysis. The energy savings attributable to the adoption of the 2001 IECC will also be reconciled with monthly utility billing data using ASHRAE's Inverse Model Toolkit algorithms (IMT) (Kissock et al. 2001) is shown in Figure 34 in 2002 utility bills should decrease by an amount that is similar to the calculated savings from 2001 IECC adoption for similar sized office, retail or industrial facility with similar characteristics and functional use. It has two parallel paths, one for the 1999 building stock and one for the 2002 building stock.

For the building cross-check with utility billing data, the procedure begins by selecting a 1999 building and a 2002 building that have similar characteristics to the construction characteristics that were used for the primary calculation. For each building 12 months of utility billing data are obtained and analyzed with the ASHRAE IMT. The resultant, valid parameters from IMT<sup>36</sup> are then normalized by conditioned area to obtain a weather-normalized, averaged energy use per square foot. After the appropriate number of buildings have been analyzed that represent a statistically significant sample of buildings constructed in 1999 for each county (or for 2002), the normalized annual consumption (i.e., expressed as kWh/yr-ft<sup>2</sup>) is compared against the similar parameter for buildings constructed in 2002 (i.e., also expressed as kWh/yr-ft<sup>2</sup>) to obtain the average electricity savings per square foot of conditioned area. This difference is then multiplied by the square footage reported in the building permits constructed in 2002 and the average conditioned area of the buildings constructed in 2002 to obtain the total annual electricity savings per county. This total, county-wide, annual electricity savings calculated by utility bill analysis can then be compared to the total, county-wide, annual electricity savings calculated by simulation. For each county, savings from the difference in 1999 versus 2002 utility bills are expected to be similar to savings calculated by simulation for similar buildings, with similar characteristics.

<sup>35</sup> These characteristics include insulation levels, glazing type, etc., as defined in Chapter 8 of the 2001 IECC or Chapter 7 of the 2000 IECC, which references ASHRAE Standard 90.1 1999 (w/o amendments).

<sup>36</sup> The primary parameter of interest from the ASHRAE IMT depends upon the model selection, which includes: a one parameter mean model, a two parameter model, three, four and five parameter change-point models, variable based degree models, and combined models that utilize multiple linear regression with 1,2,3,4,5 or VBDD models. The goodness of fit indicators used to determine a valid IMT run include the CV(RMSE), RMSE, and IMT's adjusted R<sup>2</sup>.

Cross-check of construction data using on-site visits. A reconciliation will also be carried out to cross-check selected parameters for both the 1999 and 2002 building characteristics for each county as shown in Figure 35. For the 1999 building stock, on-site surveys of a statistically significant sample will be used to cross-check the average building characteristics<sup>37</sup> used to simulate the average building in each county. Adjustments can then be made to the average 1999 characteristics should significant differences be found.

As shown in the right side of the figure adjustments will be carried out for buildings constructed in 2002 to determine if the on-site building characteristics meet, or exceed the 2001 IECC. However, differences found in the 2002 characteristics will be noted as to whether or not these differences represent characteristics that are less stringent or more stringent than code. Characteristics that are less stringent than code will be communicated with code officials to determine how procedures to the code need to be modified to better meet code requirements. Characteristics that are more stringent than code will be credited to the countywide energy savings as above code savings.

#### 5.1.2.1 Commercial/Industrial Buildings: Existing Construction

Existing commercial buildings undergo a significant remodeling are addressed by the 2000 IECC/IRC. To account for the energy savings from these activities, procedures similar to those shown for new construction will be applied to track remodeling permits, including how the buildings are complying with the 2000 IECC/IRC. Different procedures may need to be developed for tracking existing building 2000 IECC/IRC activities. For example, it may be more efficient to track the activity by the type of retrofit, including: envelope, HVAC system, etc. Once a tracking procedure has been developed, then a suitable accounting scheme can be developed and implemented to roll these savings into the savings from new construction activities.

#### 5.1.3 Renewables Applied to Buildings

The application of renewable energy systems in buildings are addressed by the 2000 IECC/IRC. To account for the energy savings from these activities, the procedures shown in Figure 36 and Figure 37 will be used to track the installation of projects that utilize renewables, according to the procedures in the 2000 IECC/IRC. In each county the number and type of renewable energy system will be evaluated to determine the displaced electricity use. Characteristics about each system will need to be collected, including: the type of system, ft<sup>2</sup> of aperture, orientation, tilt, systems characteristics, etc. These characteristics will then be input into either the FCHART or PVFCHART<sup>38</sup>, depending upon system type, and the annual energy use simulated with the appropriate program. Total county-wide energy use is the cumulative total energy production of all systems installed in a county.

#### 5.1.4 Calculation of Total Annual County-wide IECC/IRC Electricity Reductions.

Total annual, county-wide IECC/IRC electricity reductions would be the total of the savings from IECC/IRC application to residential, commercial/industrial, and renewable energy applications. Total savings from non-attainment and affected counties would incorporate savings from the county-wide IECC/IRC reductions. Total state-wide savings would be calculated in a similar fashion using county-wide savings from all Texas counties. The county-wide and state-wide models would also be used to generate either annual kWh totals, peak kW values, or 24-hour profiles, which would be needed for the hourly photochemical modeling of ozone in non-attainment and affected counties for EPA ozone day or Episode day calculations as defined in the next section.

<sup>37</sup> As previously mentioned the 1999 average building characteristics represent the average characteristics published by F.W. Dodge, CBECS and LBNL.

<sup>38</sup> FCHART and PVFCHART are nationally recognized solar analysis software developed by S.A. Klein, and W. A. Beckman at the, Solar Energy Laboratory, Mechanical Engineering Laboratory, 1500 Engineering Drive, University of Wisconsin – Madison, WI 53706.

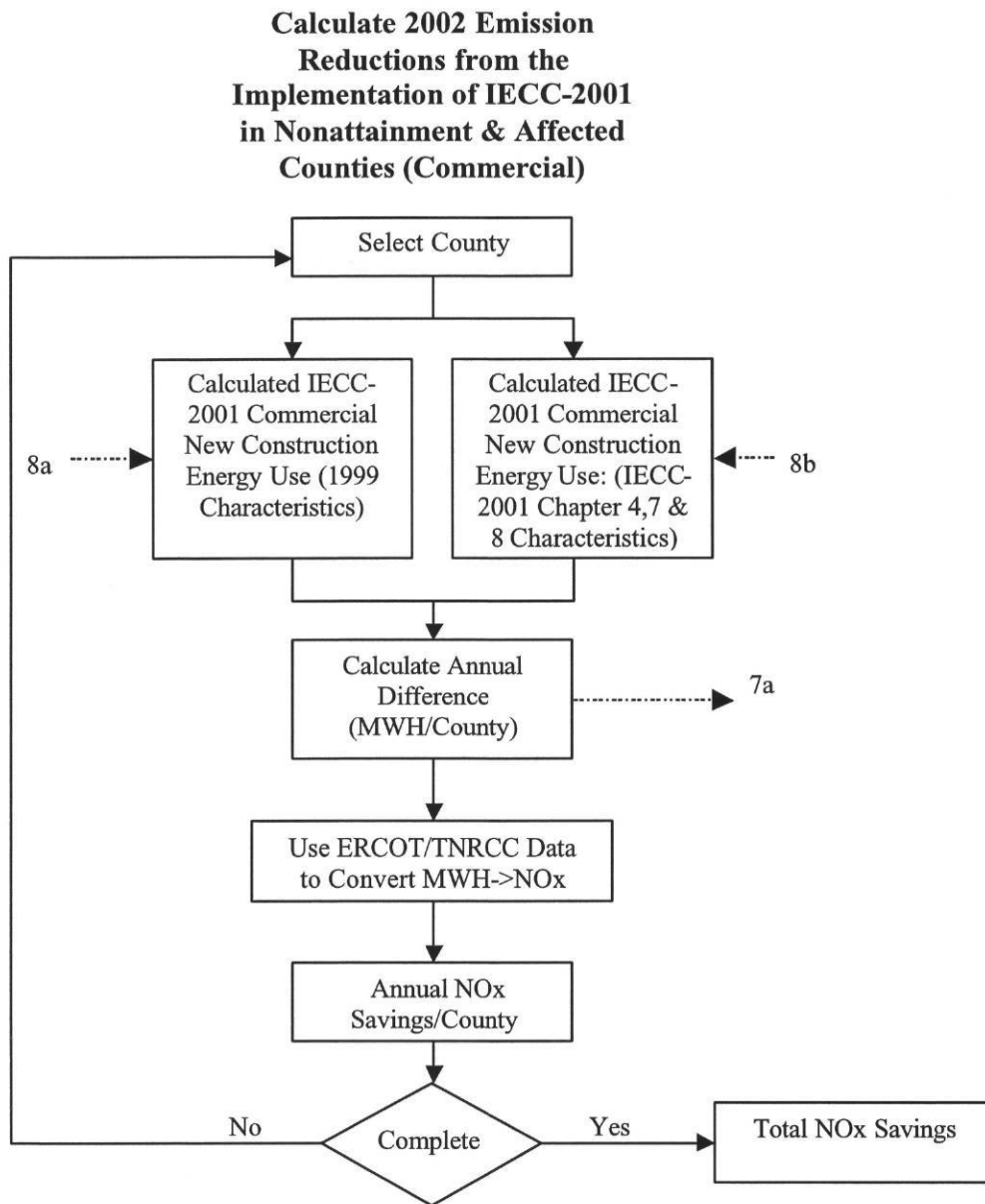


Figure 31: General flowchart for calculation of emission reductions from implementation of IECC/IRC 2001 in commercial buildings in non-attainment and affected counties.

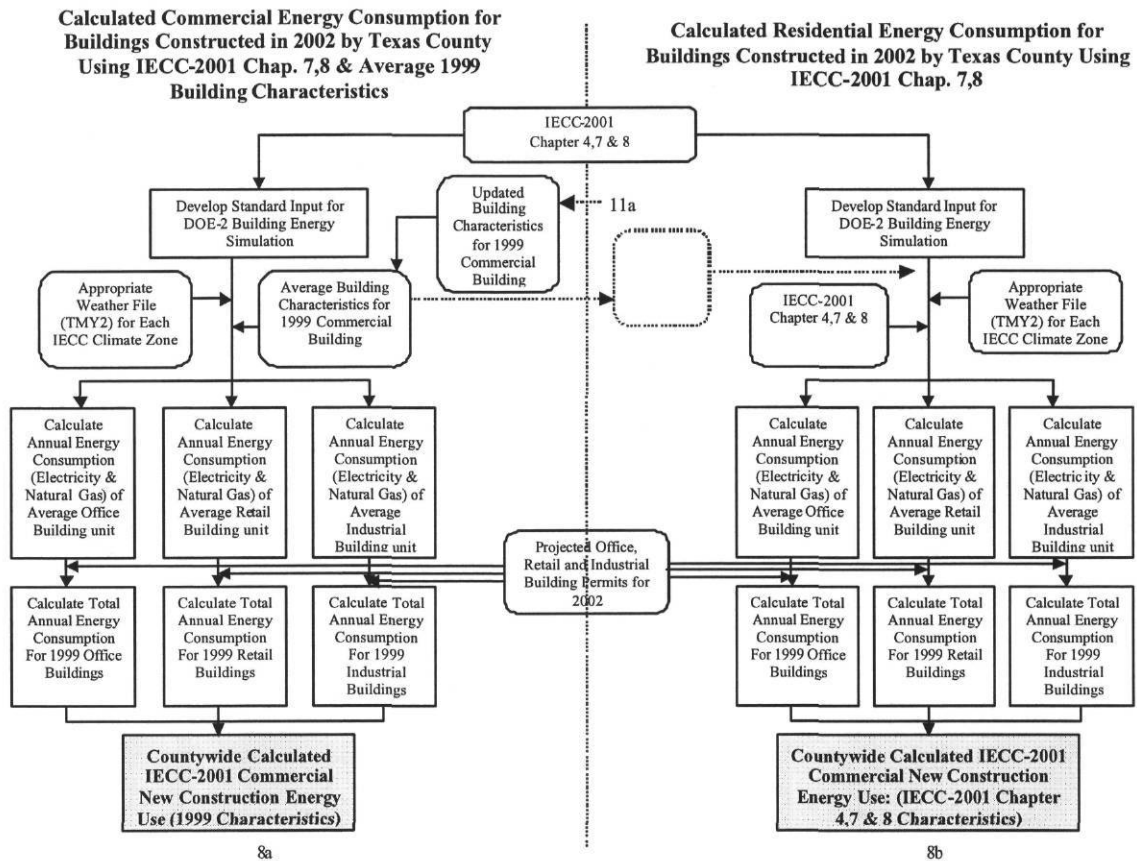


Figure 32: Calculation of countywide commercial new construction energy consumption (1999 characteristics and 2001 IECC/IRC).

### Estimated Commercial Energy Consumption for Buildings Constructed in 1999 by Texas County

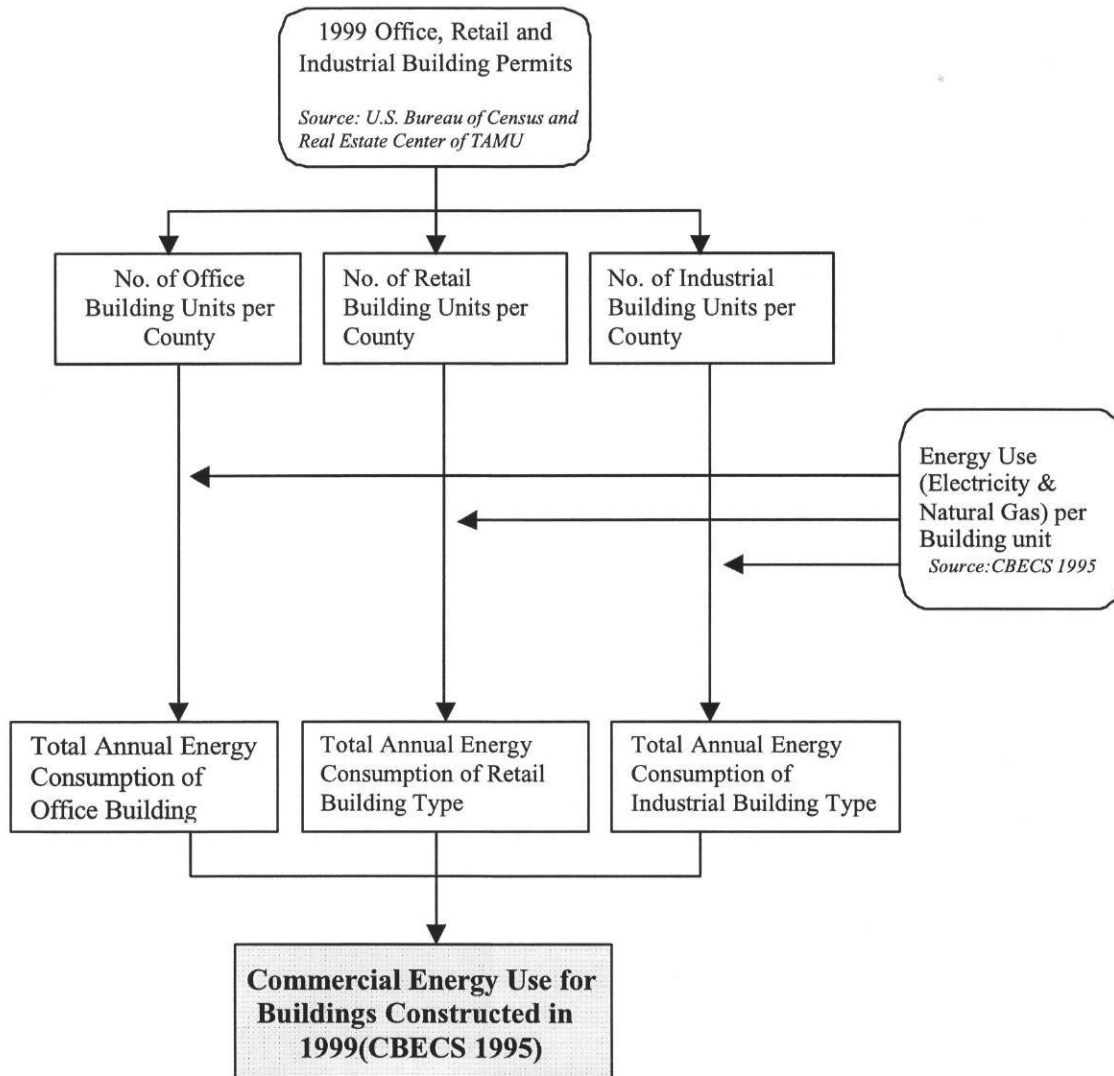


Figure 33: Estimated commercial energy consumption for buildings constructed in 1999 by Texas county.



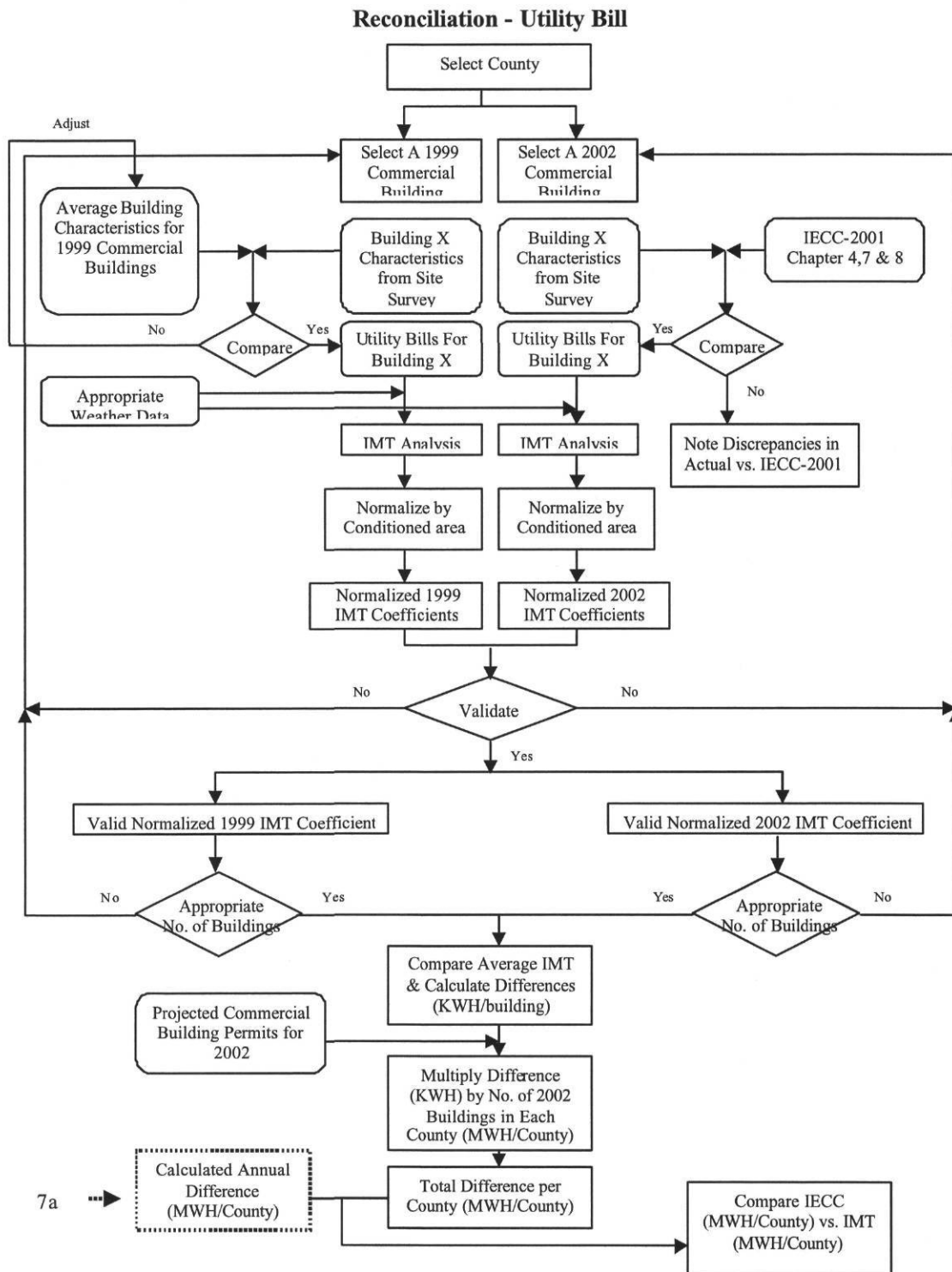


Figure 34: Reconciliation of commercial building energy savings using utility bill analysis.

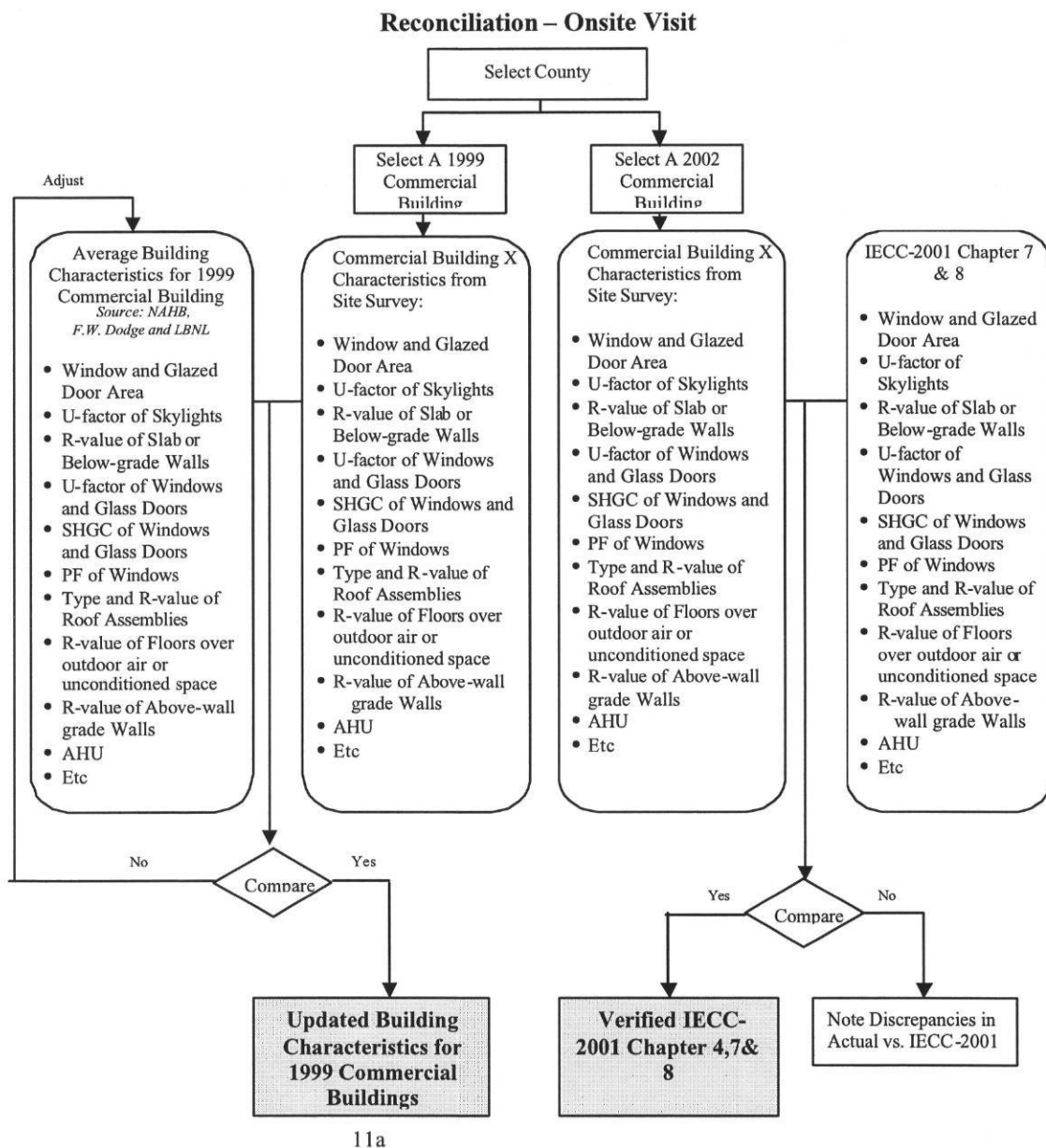


Figure 35: Reconciliation commercial building characteristics using on-site surveys.

**Calculate Emission Reductions from  
Renewable Energy Production by Texas County**

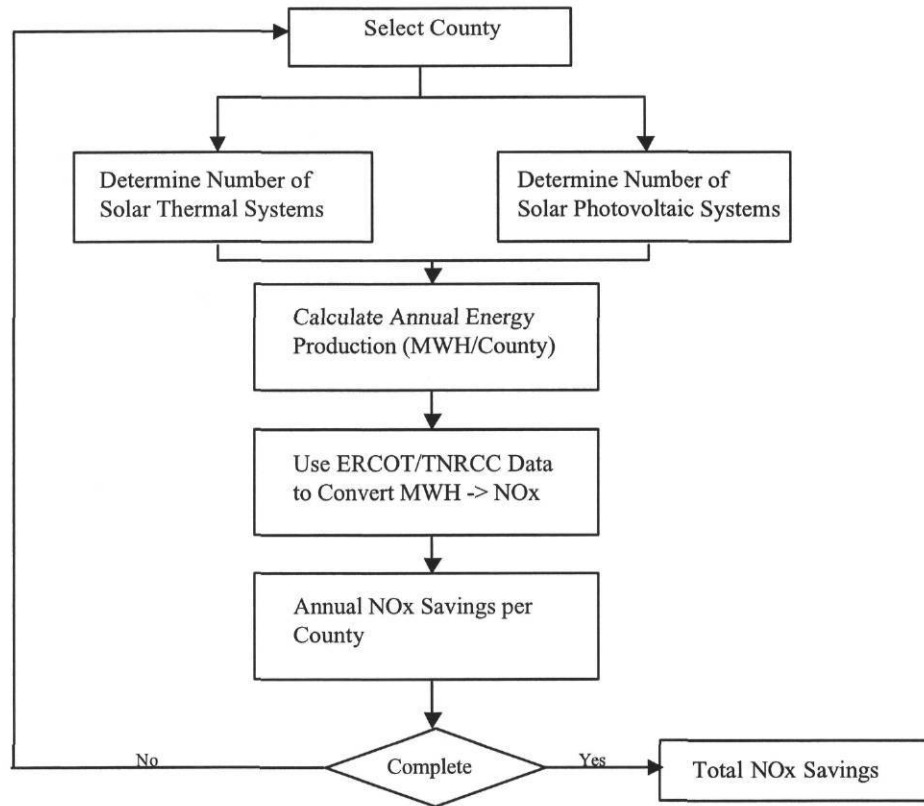
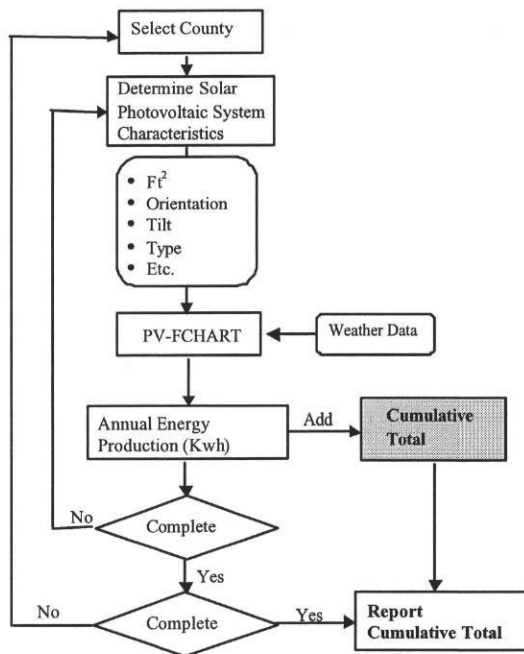


Figure 36: General flowchart for calculation of emission reductions from the use of renewables as incorporated in the IECC/IRC 2001 in residential or commercial/industrial buildings in non-attainment and affected counties.

### Calculated Renewable Energy Production for Solar Photovoltaic Systems by Texas County



### Calculated Renewable Energy Production for Solar Thermal Systems by Texas County

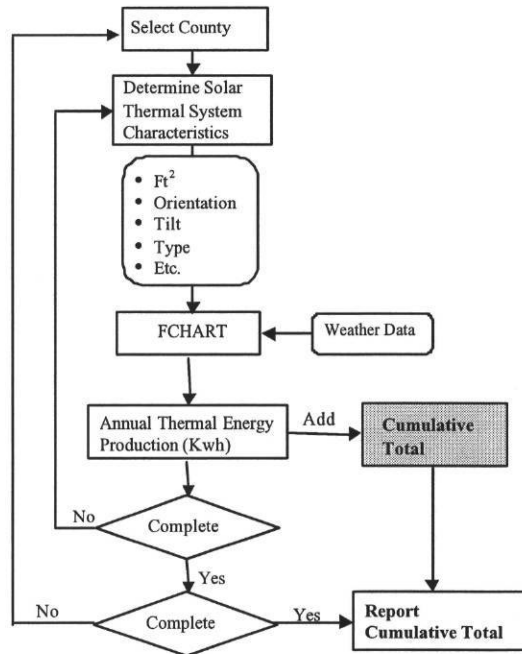


Figure 37: Detailed calculation of county-wide solar thermal or photovoltaic energy generation in residential or commercial/industrial new construction.

## 5.2 Procedures for Calculating Annual NOx Reduction Potential.

The annual NOx estimation procedure proposed by the TNRCC requires annual, county-wide kWh reductions and peak kW reductions<sup>39</sup>. This methodology estimates the NOx emission reductions resulting from the energy savings in building. The input for the methodology is the expected annual electricity savings (MWh) for 2007 for each service territory. The output of the methodology is county-wide annual NOx emission reductions from electricity generators, which are converted into daily values by dividing the annual value by 365 days.

The proposed TNRCC annual NOx calculation methodology involves the following steps as shown in Figure 38:

Step 1. Estimate the amount of electricity generation that would be curtailed in each service territory for a given amount of electricity demand savings in a particular service territory. This step would involve the calculation of county-wide electricity savings from implementation of the IECC/IRC. The calculation begins with the county-wide simulations of standard versus IECC/IRC-compliant residential, commercial and industrial buildings. These simulations use the same input files that were used to calculate the annual electricity savings (kWh) and demand savings (kW).

Step 2. Estimate the amount of generation from each plant that would be curtailed for a given amount of generation curtailment in a particular service territory. This step would be performed using the EPA's E-GRID<sup>40</sup> database, which contains information about how much electricity was exchanged between each power control area within the ERCOT region in 1998. This information is used to determine which power plant supplied the electricity.

Step 3. Combine information from the first two steps together to estimate the electricity generation reductions from each plant in the ERCOT region for a given amount of electricity demand reduction occurring in a particular service territory. This step uses the E-GRID database to estimate the location of the electricity generation reductions to the plant level within a particular power control area using E-GRID plant-level data, and includes removal of electricity generating units expected to retire by 2007, as well as the addition of new units. Units are assigned to the power production using E-GRID's plant fuel type and capacity model, which are specific to each plant.

Step 4. Apply plant specific emission factors to the curtailed generation at each plant, which are the results from step 3. In this step information from the previous steps is combined so that the generation reductions for each plant within ERCOT is determined for a given amount of electricity demand savings expected for a particular service territory.

Step 5. Cumulate the annual emission reductions at each location into county-wide totals. In this step E-GRID assigns NOx emissions factors to the generation reduction to determine the emission reductions.

Step 6. Cumulate plant-level data into county-wide data. In this step plant-level data are summarized by county to produce county-wide NOx reductions attributable to implementation of the IECC/IRC.

<sup>39</sup> For additional details regarding this procedure see: Draft Houston/Galveston Attainment Demonstration and Post-1999 Rate-of-Progress SIP: Appendix A – Description of the Methodology for Determining Credit for Energy Efficiency, Texas Natural Resources Conservation Commission, Austin, Texas, June 5<sup>th</sup>, 2002 proposal.

<sup>40</sup> E-GRID, Ver. 2, is the EPA's Emissions and Generation Resource Integrated Database (Version 2). This publicly available database can be found at [www.epa.gov/airmarkets/egrid/](http://www.epa.gov/airmarkets/egrid/).

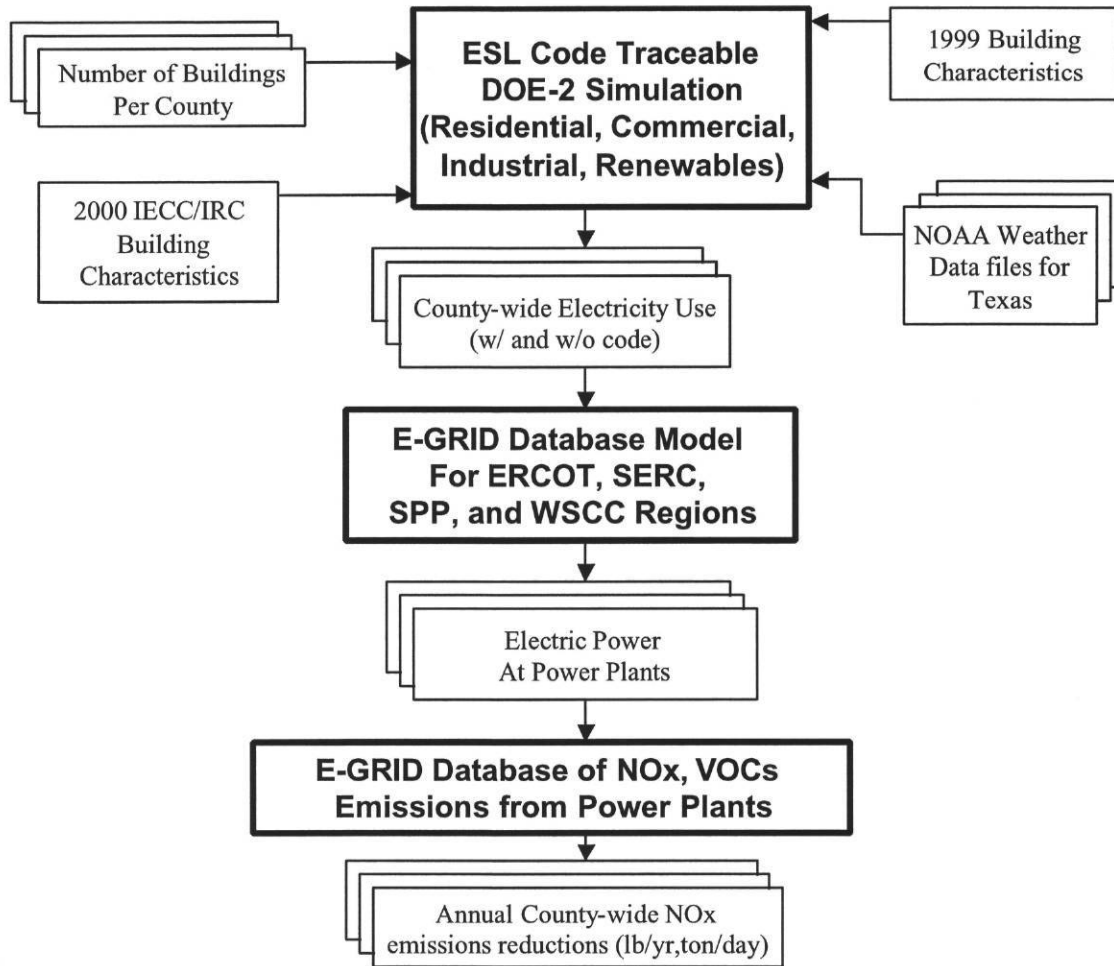


Figure 38: Annual NOx reporting procedure proposed by TNRCC (Source: TNRCC 2002)

### 5.3 Procedures for Modeling Hourly Ozone Reductions.

The proposed procedures for modeling hourly ozone reductions are shown in Figure 39. This procedure requires data and calculations from several state agencies, university labs and private entities<sup>41</sup>. As indicated in the upper portion of Figure 39, the procedure begins with the simulated, hourly, county-wide electricity savings from the implementation of the IECC/IRC to residential, commercial and industrial facilities, followed by the calculation of the electrical power production at the power plant using the appropriate grid model. The hourly, plant-specific power generation is then linked to hourly, TNRCC-measured pollutants for each plant to obtain the hourly, NO<sub>x</sub>, VOC and other pollutants associated with the power production at the time of the simulation. These hourly NO<sub>x</sub> and VOC are then merged together with other sources of NO<sub>x</sub> and VOC and fed into the hourly photochemical model along with the prevailing weather conditions to allow for the calculation of the ozone pollution. The following sections describe each of these procedural tasks in more detail.

#### 5.3.1 Calculation of Hourly County-wide IECC/IRC Electricity Profiles.

The calculation of the ozone emissions reductions begins with the county-wide simulations of standard versus IECC/IRC-compliant residential, commercial and industrial buildings. These simulations use the same input files that were used to calculate the annual electricity savings (kWh) and demand savings (kW), which are re-simulated using the EPA Ozone-day weather conditions and the August-September 2000 Ozone Episode day weather conditions<sup>42</sup>. An example of the 24-hour profile from one of these simulations is shown in Figure 40. County-wide, 24-hour electricity demand profiles are then assembled from simulations of diversified profiles<sup>43</sup>.

#### 5.3.2 Calculation of Stationary Electricity Reductions From County-wide Electricity Reductions

Files containing the hourly, county-wide simulated electricity profiles are then input to the appropriate electricity grid models<sup>44</sup>. The electric grid models then assign the power production to specific power plants, after calculating the transmission and distribution losses. Figure 41 shows the electric power grid for ERCOT<sup>45</sup>, which connects the different investor-owned utilities and municipal utilities as shown in Figure 42 shows the different Retail Electric Service regions. Specific dispatch models of power generation equipment would then selected to represent varying pollution production scenarios. These scenarios also include existing power generation plants and new power generation plants as shown in Figure 43 to allow for the evaluation of the variation in new low-NO<sub>x</sub> technologies that are expected to be introduced in the near future.

#### 5.3.3 Calculation of NO<sub>x</sub> Reductions From Stationary Electricity Reductions

These power generation scenarios for the Ozone day and August-September 2000 Episode day periods are then matched with the TNRCC-measured NO<sub>x</sub>, VOC and other pollutants associated with the specific power generation equipment at each power plant<sup>46</sup> to allow for the calculation of NO<sub>x</sub> and VOCs point sources associated with the Ozone day and Episode periods.

<sup>41</sup> These entities ultimately would include: the Energy Systems Laboratory (ESL), the Public Utilities Commission (PUC), the State Energy Conservation Office (SECO) for the calculation of county-wide, hourly electricity profile changes, ERCOT, SERC, SPP and WSCC for the calculation of county-wide to power plant electricity production, the TNRCC for the measured NO<sub>x</sub> and VOC data, and the ozone modeling to be performed by the Center for Energy and Environmental Resources (CEER) at the University of Texas.

<sup>42</sup> The use of the EPA ozone-day weather conditions and August-September 2000 Ozone Episode day is proposed to allow the EPA to assess the progress of Senate Bill 5 against the original SIP, which also used similar weather definitions to drive the photochemical model.

<sup>43</sup> This diversification procedure is used to develop a county-wide profile that represents the smoothed, electricity consumption of 1,000s of buildings, and consists of statistically randomized runs of the IECC-traceable simulation program.

<sup>44</sup> The appropriate electricity supply grid model is determined by the location of the county within the state. Depending upon where the county is located, models from ERCOT, SERC, SPP and WSCC will need to be used to determine which power plant supplied the electricity to that county, during the period of the simulation.

<sup>45</sup> Source: Electricity Reliability Council for Texas (ERCOT 2002).

<sup>46</sup> Or NO<sub>x</sub>, VOC amounts anticipated for future plants.



### 5.3.4 Calculating NO<sub>x</sub> Reductions From Other County-wide Area Sources (ESL)

The calculated NO<sub>x</sub> and VOC sources from the electric power generation associated with IECC/IRC county-wide simulations are then merged with other sources of NO<sub>x</sub> and VOCs, including: on-road mobile, off-road mobile, area sources, biogenic and other sources. These other sources need to include anticipated decreases from other factors, including TNRCC Rule 117 that limits the NO<sub>x</sub> production of combustion sources, as well as other known, traceable reductions<sup>47</sup>.

### 5.3.5 Procedures for Calculating Ozone Reductions From NO<sub>x</sub> Reductions (CEER)

As a final step, ozone reductions are calculated from NO<sub>x</sub> reductions traceable to the IECC/IRC implementation using the same photochemical modeling procedures<sup>48</sup> that were used to demonstrate the ozone reductions in the State Implementation Plan (SIP) approved by the EPA. The procedures utilize the NO<sub>x</sub> and VOC inputs from the TNRCC database, the calculated NO<sub>x</sub> and VOC reductions traceable to the IECC/IRC implementation, which are then simulated with state-wide ozone-day and August-September 2000 episode day weather conditions for Texas.

These projections of ozone reductions are then periodically compared against ozone measurements from the TNRCC measurement sites shown in Figure 44. Such measurements form the basis for classification of ozone concentrations as shown in Figure 45

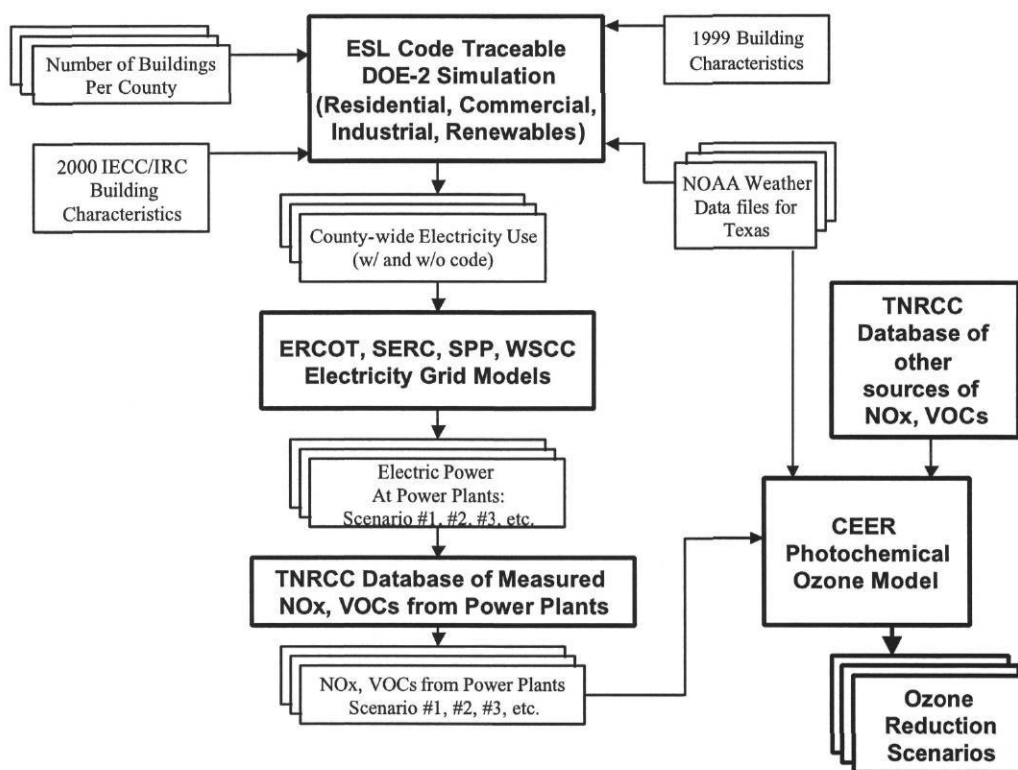


Figure 39: Analysis process for calculating emissions reductions from IECC/IRC implementation.

<sup>47</sup> For example, communications several HVAC manufacturers and with GAMA have indicated that most manufacturers of residential furnaces have eliminated the pilot lights in their residential units to achieve the higher AFUE mandated by Federal law. This is estimated to be in the range of 500 to 800 Btuh of open-flame combustion per household. This becomes important when one realizes that about 5 - 10% of all households replace their furnaces in a given year, which can equal or exceed the number of new housing starts in a county. Similar reductions in pilot lights are expected for domestic water heaters and other gas appliances.

<sup>48</sup> The photochemical modeling performed by the Center for Energy and Environmental Resources (CEER) at the University of Texas.

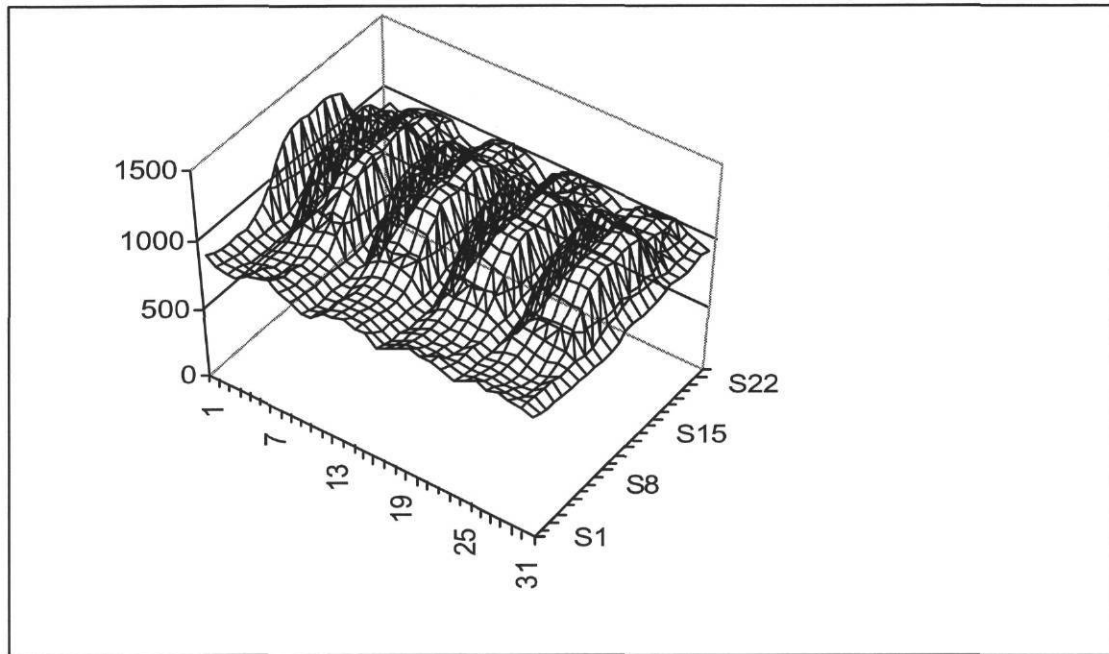


Figure 40: Example of typical county-wide, 24-hour electricity usage profile.

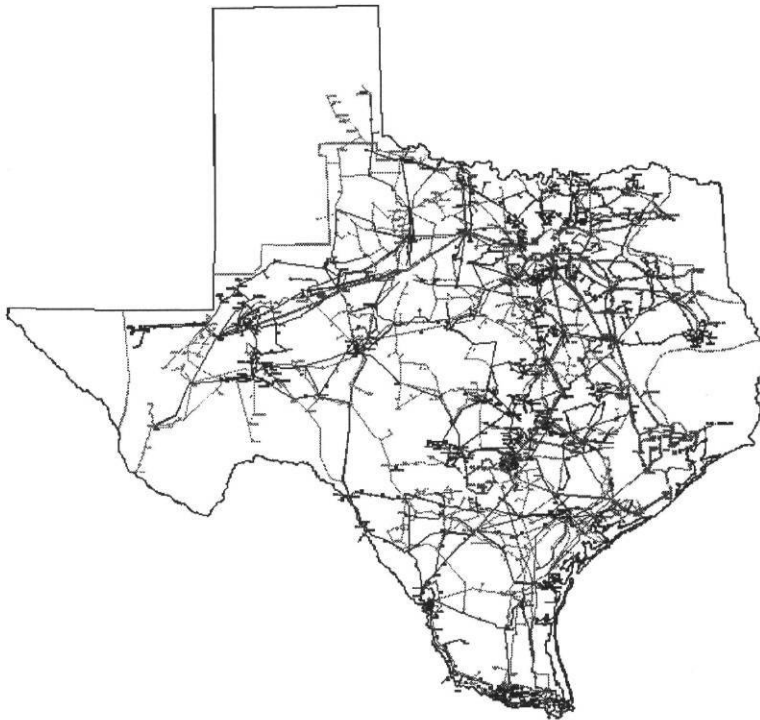


Figure 41: Texas electricity power grid (Source: ERCOT 2002).

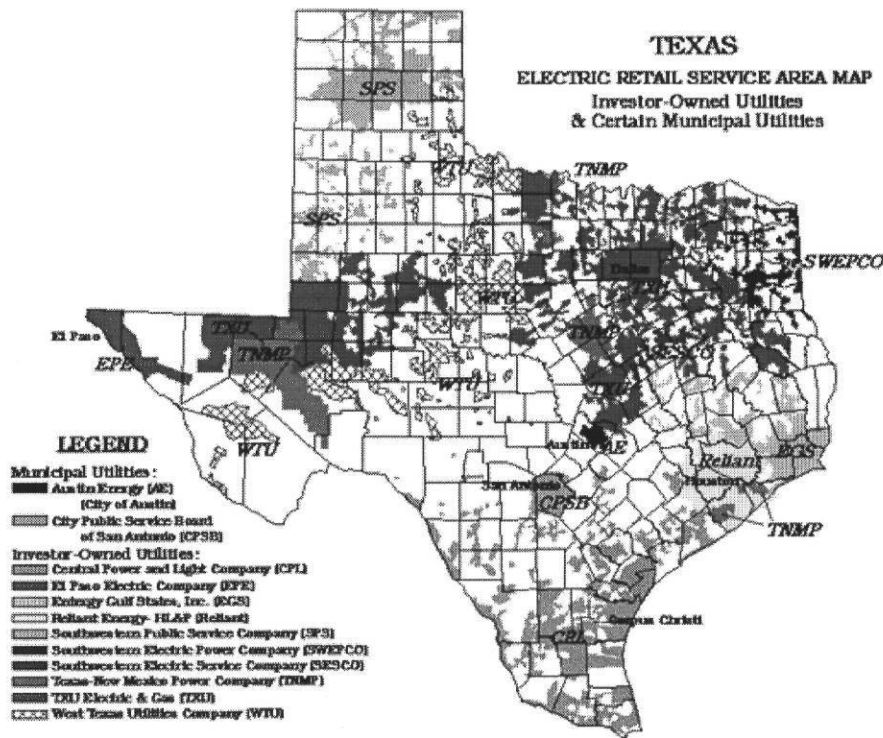


Figure 42: Texas electric retail service map (Source: TNRCC 2002).

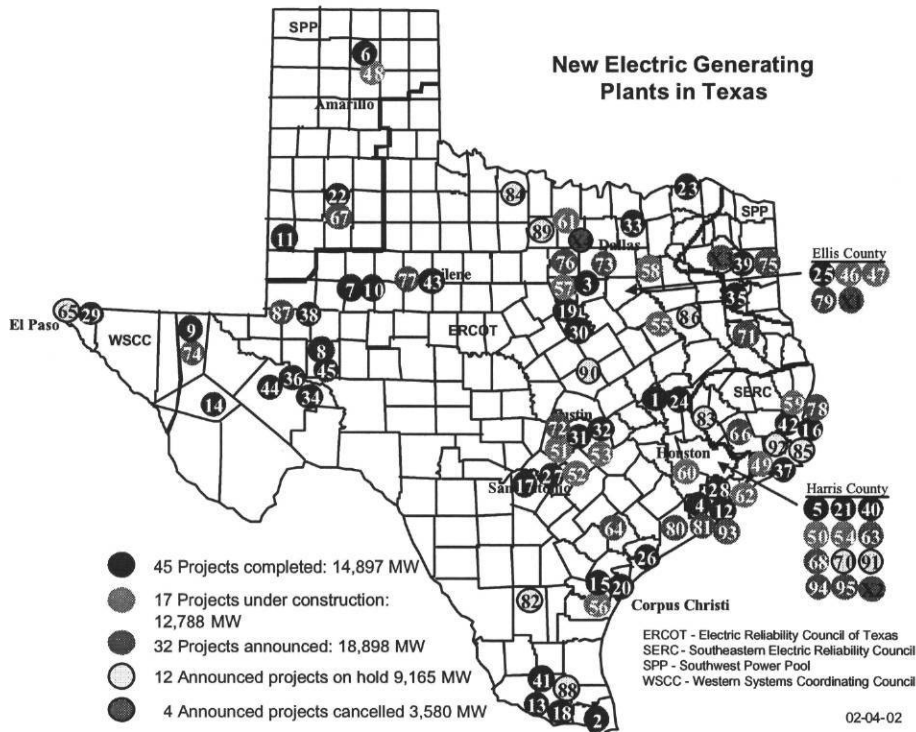


Figure 43: New electric generating plants in Texas (Source: TPUC 2002).

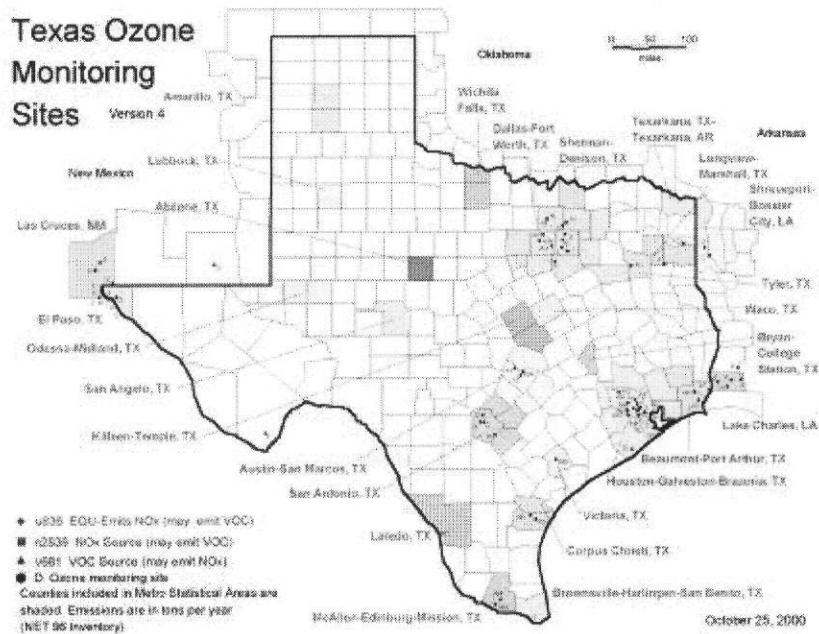


Figure 44: Texas ozone monitoring sites.

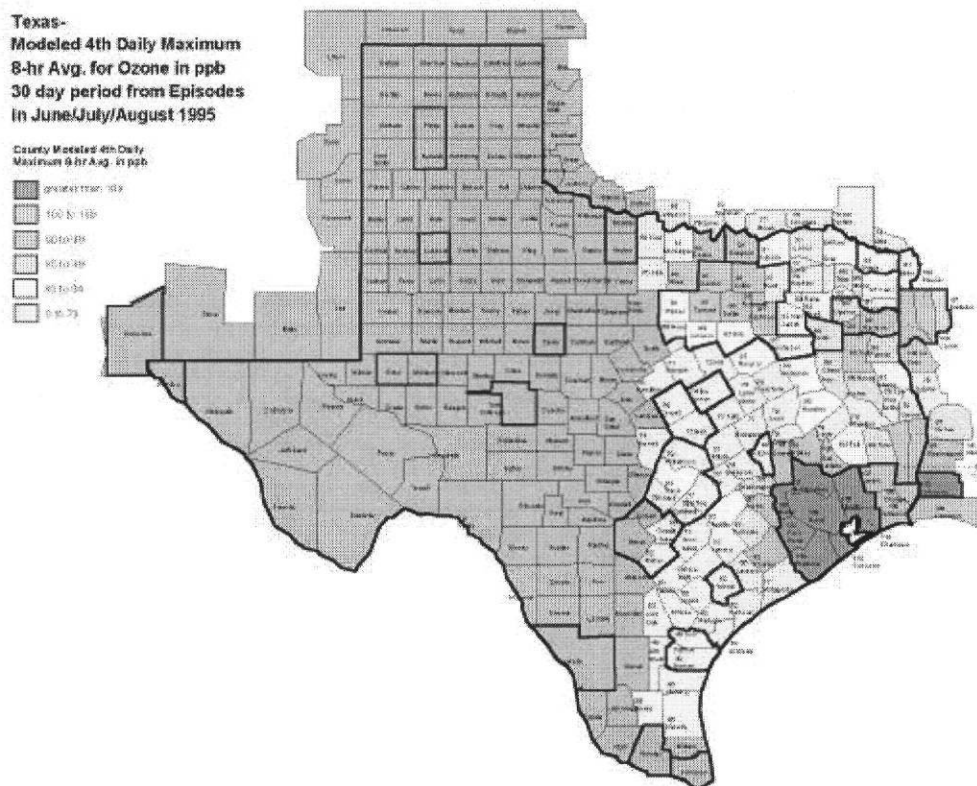


Figure 45: June/July/August 1995 episode day ozone concentrations.

## 6 TECHNOLOGIES FOR REDUCING ENERGY USED IN BUILDINGS

Adoption of the 2000 IECC/IRC has allowed the state of Texas to define minimum energy performance for new buildings and for existing buildings that are remodeled. In this section of this report technologies are briefly reviewed that can have a substantial impact on delivering above-code building performance for residential, commercial and industrial buildings in Texas Buildings.

In general for residential buildings, the 2000 IECC/IRC provides prescriptive measures for each climate zone in Chapters 5 and 6 to assure that new construction meets a minimum, predictable energy use. A residential performance path is provided in Chapter 4. Commercial buildings are addressed by minimum prescriptive measures in Chapter 8 of the 2000 IECC/IRC, or by minimum performance measures using ASHRAE Standard 90.1 1999<sup>49</sup>, which is referenced by Chapter 7. More stringent design efficiency measures for commercial buildings can be found in programs such as the U.S. Green Building Council's LEED ratings<sup>50</sup>.

### 6.1 Building Envelope

Energy efficient technologies for building envelopes include well-known technologies for insulation and newer technologies such as low-E windows, reflective roof coatings, structurally integrated panels (SIPs) and radiative barriers, as indicated in the next section.

#### 6.1.1 New Construction

New construction has a many new envelope technologies for contractors and homeowners to choose from, depending upon budget, housing type and climate zone. Examples include improved low-E windows, and ventilated windows (commercial buildings), high albedo, or highly reflective roofs<sup>51</sup>, improved shading devices for windows, which can be combined with daylighting features such as lightshelves, improved building sealing techniques such as building wraps, and sealants, reflective barriers in attics and cavities. Some residential builders are now experimenting with reducing thermal loads by reducing the exterior envelope area by using a compact two story designs that also allows for ductwork to be incorporated into the floor trusses, which reduces heat gain when compared to their traditional placement in the hot attic.

#### 6.1.2 Existing Construction

Existing homes can also be improved by replacing old, single pane windows with low-E windows, installing reflective roofing, improving building infiltration using blower door testing and duct blasters, and retrofitting reflective barriers inside attics to help reduce summertime temperatures.

### 6.2 Lighting/Daylighting

New technologies for reducing the energy use of lighting systems has improved dramatically in recent years. Almost daily, new energy efficient light sources appear on the store shelves for residential and commercial applications, most notably compact fluorescents, T8 and now T5 fluorescent lamps in almost all shapes and sizes.

<sup>49</sup> Chapter 7 of the 2000 IECC/IRC, references ASHRAE Standard 90.1, 1989, which is amended to ASHRAE Standard 90.1 1999, (w/o amendments) in the 2001 Supplement (published in March 2001), which is directed by Senate Bill 5's effective date of May 1<sup>st</sup>, 2001.

<sup>50</sup> The Leadership in Energy and Environmental Design (LEED) Green Building Rating System is the voluntary, consensus-based, market-driven building rating system of the U.S. Green Building Council that is used to evaluate environmental performance from a whole-building perspective over a building's life cycle and to provide a definitive standard for a "green building". Different levels of green building certification are awarded based on the total credits earned. The U.S. Green Building Council (USGBC 2002), founded in 1993, is a non-profit organization that provides knowledge and action on environmental issues for commercial and industrial buildings. The headquarters are located in San Francisco, California. The council has grown to more than 500 leading international organizations. Its goal is to help the building industry develop products that are more environmentally and economically viable and to drive the marketplace forward towards the development of high performance buildings (U.S. Green Building Council 2002).

<sup>51</sup> In the hot and humid south highly reflective roofs usually will require periodic washing to remove dirt, mold and mildew that can reduce the roofs thermal reflectance.

### 6.2.1 New Construction

Many more architects are becoming comfortable using daylighting systems that reduce lighting energy use by redirecting natural light deep into building interiors without increasing summertime heat gain. Such systems are most effective when combined with automatic dimming systems so building occupants do not have to constantly adjust the lighting levels. New systems have begun to appear that channel solar radiation, captured with sun-catchers, into building interiors using fiber optics. This same technology can provide lighting at night using a central HID source that is then channeled to luminaries through switchable fiber optics. Heat from the central HID source can then be effectively captured and reused or rejected. Lighting systems with combined motion sensors, and automatic dimming features are also becoming popular.

### 6.2.2 Existing Construction

Retrofitting existing T12 fluorescent lamps<sup>52</sup> with either T8 or T5 lamps is a cost effective method for reducing lighting energy use in office buildings, grocery stores, retail stores, and other facilities that currently use T12 fluorescent lighting. Such retrofits reduce the lighting energy use primarily by replacing the older magnetic ballasts<sup>53</sup> with new electronic ballasts that consume a fraction of the electricity use. Such lighting retrofits can also include automatic switching provided by motion sensors, lighting sensors in perimeter lighting applications or a combination of motion and lighting sensors. Reducing the installed lighting load also decreases the required cooling load, with a slight heating penalty for winter months.

## 6.3 Appliances

Energy efficient technologies for appliances vary according to application (i.e., residential or commercial) as indicated in the next section.

### 6.3.1 Residential

Significant improvements have been made in developing and delivering energy efficient refrigerators for household use, which represent a sizable portion of household electricity use. Since the mid 1980s refrigerators have made significant advances in reducing thermal losses, and improved refrigeration cycles, without significant price increases to customers.

Other appliances in the kitchen have made efficiency improvements as well. For example, microwave ovens are in use in many kitchens that are capable of heating food with a fraction of the energy used by traditional electric or gas ovens. Convection ovens also offer some efficiency improvements over conventional ovens, as does induction (i.e., magnetic) stoves.

In the laundry room, significant energy and water savings are available with horizontal axis washing machines. Such clothes washing machines use less water, less detergent and less energy than vertical axis machines and reduce the time needed for drying because of their ability to incorporate a high-speed extraction cycle that removes additional amounts of water, which would have been removed in the dryer. Although such machines currently carry a premium price tag, reduced prices are expected as additional manufacturers offer competing models. Microwave clothes dryer R&D has also been reported by several manufacturers.

Use of the internet in a home can either increase or decrease energy use, depending several variables. Increases in energy use come from the energy used by the PC to connect to the internet, the modem used to connect to the internet (i.e., dial-up, cable or other modem), increased use of A/C or heating where none may have been used before, lighting energy use in the room, etc. Decreases in energy use come from

<sup>52</sup> The T12 designation refers to the diameter of the fluorescent lamp, where T12 lamps would be 12/8" in diameter, T8 would be 8/8" in diameter, or 1", and T5 lamps would be 5/8" in diameter.

<sup>53</sup> Lighting ballasts are necessary for fluorescent lighting to control the flow of electricity once the arc is struck between the electrodes in the lamp, which would otherwise draw an uncontrolled amount of current.



reduced travel by the individual who is now surfing the web, versus cruising the streets in a car, and improvements in efficiency of communication using email, etc.

### 6.3.2 Commercial Buildings

In commercial buildings, steadily increasing internal loads, due in part to the computerization of the office environment, have begun to level-off as LCD computer screens have become competitive with the traditional CRT displays. Increasing use of laptop computers has further reduced computer energy use. Energy efficiency has also spread to office copiers, printers, and other equipment. Teleconferencing continues to increase in use, which results in travel cost savings. Cell phones and Personal Digital Assistants (PDAs) continue to make office workers more effective workers, which can have an indirect energy savings as companies downsize, and load more clerical and administrative tasks onto their workers.

Use of the internet at work can either increase or decrease energy use, also depending several variables. Increases in energy use come from the energy used by the PC to connected to the internet, the modem used to connect to the internet (i.e., dial-up, cable or other modem), increased use of A/C or heating where none may have been used before, lighting energy use in the room, etc. Some studies have shown that employee productivity can decrease significantly if "personal" internet use at work is not closely monitored, which can indirectly affect energy. Decreases in energy use come from reduced travel by the individual who is now surfs the web to find information, versus numerous phone calls or trips to find the same information. Use of the email for distribution of sales material, brochures, etc. has also significantly decreased printing costs for many businesses, which can indirectly affect energy use.

## 6.4 Heating/Cooling Systems

Energy efficient technologies for heating and cooling systems vary according to construction type (i.e., residential, commercial, etc.). Technologies vary as well for new construction and existing construction, as indicated in the next section.

### 6.4.1 Residential: New or Existing Construction

Efficiency improvements in residential heating and cooling systems have also made significant contributions towards reducing household energy use. High efficiency air conditioners are now available from many manufacturers (i.e., SEER 11, 12, and 13), and when properly sized to meet the peak load, can significantly reduce summertime electricity bills. The technologies for accomplishing this vary from one manufacturer to the next, and include such innovations such as dual speed systems, variable speed systems, improved coil design (i.e., evaporator and condenser coils), and the ever increasing use of microprocessors similar to what has happened in the automotive industry.

Improvements to residential heating and cooling systems have also been accomplished through the introduction (or reintroduction) of new systems. Such systems include minisplits or ductless air conditioners<sup>54</sup>, ground-coupled heat pumps, direct/indirect evaporative cooling (in the hot and dry parts of Texas). New combinations of systems can also deliver improved total performance. For example, air-conditioning systems that use the domestic water heater for space heating instead of a furnace, and systems that supplement domestic water heating with waste heat recovery from the air conditioner's condenser.

Residential furnace efficiencies have also continued to improve as well. One improvement of note for NOx reductions is the replacement of the pilot light with a hot surface ignition system. This eliminates the 500 to 800 Btu/h energy use of the pilot light<sup>55</sup>, which contributes to the summertime ozone production if the pilot light is burning during the summertime.

<sup>54</sup> A minisplit air conditioning system is similar to a window air conditioner, only the unit consists of two parts, an indoor evaporator coil/blower, and an outdoor condensing unit and compressor, connected by refrigeration and control lines. Minisplits are more common in commercial buildings, and have seen wide-spread use in other countries.

<sup>55</sup> 500 to 800 Btu/h is equal to about at 150 to 250 Watt light, and produces considerable NOx since the flame is an open flame.



Residential heating/cooling system efficiencies can also improve with the use of programmable thermostats<sup>56</sup>. Residential economizers are also being investigated for those climate zones where cool, dry evening conditions allow for their use<sup>57</sup>.

Efficiency improvements have also been reported in the design of residential ductwork. Most notably, increased insulation levels, and improved sealing techniques for ductwork exposed to the severe conditions in the attic, and in several showcase homes, relocation of the ductwork and air-conditioning system inside of the conditioned envelope, usually through the use of a chase located in the ceiling of the hallway, or by using ducts that are threaded between floor trusses.

## 6.4.2 Commercial Buildings

### 6.4.2.1 New Construction

In commercial buildings the list of technology improvement is longer. Many of these improvements rely on new or improved equipment, including: variable-volume dual or single duct systems, which use low static pressure duct distribution system, over-sized, low-head cooling towers, variable-speed chilled/hot water pumping, and high efficiency chillers, pumps, and electric motors. New blowers often utilize advanced air-foil technologies for improved efficiency. Some new systems are also being designed to minimize ductwork<sup>58</sup>, which reduces installation costs, and improves efficiency.

Other new technologies include dual-path, pre-conditioning systems, which in the south utilize cooling coils to efficiently remove humidity from the incoming air, water-loop, ground coupled heat pumps<sup>59</sup>, cool ceilings<sup>60</sup>, cool beam systems<sup>61</sup>, personal heating/cooling systems<sup>62</sup>, thermal storage systems, and thermostats that also utilize occupancy sensors.

Significant improvements in efficiency are also being reported from the application of optimum control strategies for cooling/heating systems, most commonly where temperatures and flow rates are reduced to meet only what is required on a minute-by-minute basis. Many architects and engineers are also requiring performance testing of new construction before a building is signed-off to assure that the building meets the design and performance specifications.

### 6.4.2.2 Existing Construction

Several important studies have shown that building heating/cooling system performance degrades over time. Such degradations decrease the system's ability to deliver comfort conditions, and more importantly to the State's emissions problems, increases the building's energy use. To help improve this problem, the Energy Systems Laboratory developed the Continuous Commissioning<sup>SM</sup> or CC<sup>SM</sup> process. Continuous Commissioning<sup>SM</sup> is a process where the Laboratory staff investigates and documents areas where the performance of the mechanical systems can be improved, and working closely with the building operators, makes the changes necessary to improve performance, and documents the savings with hourly measured data. Continuous Commissioning<sup>SM</sup> has produced average savings in the range of 20%, and sometimes saves as much as 40% of a building's heating/cooling energy use. Many retrofit opportunities exist for commercial buildings as well, and include almost all the same measured listed for new construction. Research is also being performed at the ESL and the U.S. Department of Energy's National Laboratories to

<sup>56</sup> This is required by the 2000 IECC/IRC for new construction.

<sup>57</sup> One research effort is underway by the California Energy Commission where residential economizers are being investigated for use in low cost housing.

<sup>58</sup> Reducing the ductwork usually means closer coordination of the system layout during the design process. Several new buildings are being designed with ductless, under-floor distribution systems.

<sup>59</sup> These are being increasingly used in new K-12 schools.

<sup>60</sup> Cool ceilings have seen greater use in Europe where outside humidity conditions are less. Such systems are similar to radiant ceiling panels, with the difference that chilled water is circulated in the panels to keep the ceiling cool, which cools the adjacent room by radiation and convection. Such systems have improved performance because air-handling units can be downsized to ventilation air requirements (i.e., 10 to 20% of their traditional size).

<sup>61</sup> Cool beam systems are cooling systems where cooling coils are incorporated into the overhead lighting fixtures.

<sup>62</sup> Personal heating/cooling systems are often incorporated into modular office furniture systems that utilize under-floor air distribution. Improved performance is accomplished by allowing for more individualized comfort controls. Such systems also report improved user satisfaction, which is claimed to increase office productivity.

develop and test automated fault detection and diagnostics that promise to provide additional benefits from keeping a building tuned.

## 6.5 Low NOx Technologies for Building Systems

Low NOx combustion technologies for gas consuming systems in buildings vary according to construction type (i.e., residential, commercial, etc.) and include technologies for new construction and existing construction. Gas consumption in residential includes: heating systems, domestic water heating, kitchen appliances (i.e., stoves, ovens, ranges, etc.), and clothes dryers. In commercial buildings, low NOx combustion technologies are most often applied to larger boilers and furnaces that provide buildings with heating. Recently, with the advent of TNRCC rule 117, low NOx technologies are being applied to domestic water heaters.

In general, low NOx combustion technologies in residential and commercial applications rely on down-sized technology developed by the electric power generation industry, including: low NOx burners and ultra-low NOx burners. Other industrial technologies include less excess air (LEA) technologies, air staging, over fire air, fuel reburning, flue gas recirculation, water and steam rejection, reduced air preheat, combustion optimization, oxygen-enriched combustion, and catalytic combustion. Post combustion technologies include: selective non-catalytic reduction (SNCR), selective catalytic reduction (SCR), low temperature SCRs, catalysts, and other technologies<sup>63</sup>

## 6.6 Industrial

Opportunities for reducing energy use in industrial applications are also significant and include many of the same technologies used in commercial buildings, including: energy efficient electric motors, variable speed drives, computerized control systems, high efficiency chillers, pumps and boilers, and air-foil technologies for improving blower efficiencies. Other energy efficiency improvements have also been reported through the introduction of induction and microwave heating, cogeneration, improved steam systems, and waste heat recovery. Additional information about the numerous energy conservation opportunities for industrial applications in Texas can be found in the proceedings of the Industrial Energy Technology Conference<sup>64</sup>.

## 6.7 Other

Significant opportunities exist for reducing energy use in other commercial applications. In the following section, opportunities in restaurants and grocery stores are briefly discussed.

### 6.7.1 Restaurants

Significant energy efficiency improvements have been reported in the restaurant field, including the use of improved grilling equipment<sup>65</sup>, refrigerator-freezer combinations that reduce infiltration into freezers by placing the entrance to the freezer inside the cooler, the use of industrialized, pre-prepared foods<sup>66</sup>, convection ovens, combined air-conditioner/DHW heat recovery, infrared grilling, and optimal start of appliances to reduce peak electric demand<sup>67</sup>.

### 6.7.2 Grocery Stores

<sup>63</sup> For more information about NOx reduction technologies, see the Special Report on NOx Reduction Technologies published by the Texas Institute of Advancement of Chemical Technology (TIACT 2000).

<sup>64</sup> The Industrial Energy Technology Conference, Energy Systems Laboratory, Texas A&M University, College Station, Texas 77843, [www-esl.tamu.edu](http://www-esl.tamu.edu).

<sup>65</sup> For example the use of computerized, double-sided grills at McDonalds.

<sup>66</sup> For example, the use of pre-packaged salads at McDonalds.

<sup>67</sup> Cooking equipment in restaurants draw large amounts of electricity when they are first turned on. In many cases, the peak electric demand for a restaurant can occur in the morning when equipment is first turned-on. Staggering the start of such equipment to avoid simultaneous starting of appliances can reduce the peak monthly electric demand.

Reduced energy use in grocery stores has also been reported by the major chains. Efficiency improvements have been reported through the use of refrigerator-freezer combinations, domestic water heat recovery from condensers, desiccant dehumidification from refrigeration heat rejection, rack-mounted, staged-compressors to improve refrigeration performance. T8, T5 and HID in-store lighting, and the use of daylighting.

## 6.8 Renewables

Renewable energy technologies offer significant opportunities for reducing energy use and include opportunities for solar thermal applications (i.e., active, passive), and photovoltaic (i.e., PV, BIPV).

### 6.8.1 Solar Thermal Systems

Solar thermal systems have most often been applied to new and existing residential and commercial to provide heating of domestic water and space heating. Such systems utilize active and passive delivery systems, where active delivery requires blowers and/or pumps. Passive delivery is usually accomplished without the use of blowers or pumps. The use of solar thermal systems to provide cooling in hot and humid climates is less used. A few installations have also reported the use of active solar systems that provide cooling to buildings using absorption or desiccant refrigeration systems. However, such systems can be expensive and require special maintenance.

### 6.8.2 Solar PV, and BIPV Systems

The use of photovoltaic (PV) solar systems in residential and commercial buildings continues to grow. Installation of systems can be accomplished in new or existing sites. However, although costs have improved considerably in the last few years, the cost of such systems continues to be a restriction for wide-spread applications. Such systems can utilize grid-connected PV, independent PV, or building integrated PV (i.e., BIPV) systems. Recent advances in solar systems also include the development of combined solar thermal/PV systems. Such systems collect electricity and thermal energy from the same solar panel. In Texas, the most current information about available solar systems, and solar system installation contractors can be found by contacting the Texas Renewable Energy Industries<sup>68</sup> Association

## 6.9 Thermal Comfort and Indoor Air Quality

Any discussion about reducing energy use in buildings in hot and humid climates is not complete without a discussion of the needs to maintain proper thermal comfort and indoor air quality. In the United States ASHRAE is the primary organization for developing and promoting standards for proper comfort conditions and indoor air quality<sup>69</sup>. Such standards describe acceptable conditions for thermal comfort, which include temperature and humidity conditions and ventilation requirements. In any building, sources of indoor air pollution should be reduced or placed in a controlled environment. In practice, this can be difficult and expensive to accomplish, requiring extra ducts to provide for exhaust and makeup air, special filtration systems (i.e., HEPA/UV systems<sup>70</sup>). In new commercial buildings, CO2 ventilation control is being used to provide the needed fresh air, at minimum outside air levels.

<sup>68</sup> The Texas Renewable Energy Industries Association can be reached at P.O. Box 16469, Austin, Texas 78761-6469, 512-345-5446, [www.treia.org](http://www.treia.org).

<sup>69</sup> Such standards include ASHRAE Standard 62-1999: Ventilation for Acceptable Indoor Air Quality, and ASHRAE Standard 55-1992: Thermal Environmental Conditions for Human Occupancy, Including ANSI/ASHRAE Addendum 55a-1995.

<sup>70</sup> HEPA/UV systems remove indoor contaminants using filtration and sterilization using ultraviolet light.

## 7 ESTIMATED NOX REDUCTION POTENTIAL FROM IMPLEMENTATION OF THE IECC/IRC

### 7.1 Calculations Required for Analyzing Implementation of IECC/IRC.

A complete reporting of the savings from the implementation of the IECC/IRC requires tracking and analyzing savings to new construction and construction activity to existing buildings that undergoes a building permit. Adoption of the 2000 IECC/IRC is expected to impact the following types of buildings:

- single family residential
- multifamily residential
- commercial buildings
- industrial buildings
- renewables

Adoption of the 2000 IECC/IRC is also expected to impact construction activity in existing buildings that undergoes a building permit. Such activity would impact the following types of buildings:

- single family residential
- multifamily residential
- commercial buildings
- industrial buildings
- renewables

The following section reports preliminary estimates of the energy savings associated only with new construction activity in single-family residences. Calculation of energy savings adoption of the 2000 IECC/IRC in multifamily, commercial building, industrial building and renewables needs to be developed.

### 7.2 Preliminary Estimations of Savings From Implementation of IECC/IRC to New Single-family Construction.

In this section of the report preliminary estimates are given regarding the potential electricity reductions and emissions reductions from the implementation of the IECC/IRC to new single family residences in the non-attainment and affected counties. The procedures to accomplish this were previously outlined in Section 5 of this report. First, new construction activity by county had to be determined, then energy savings attributable to the IECC/IRC had to be modeled using the code-traceable, DOE-2 simulation program, next, estimates of the NOx reduction potential from the electricity reductions in each county were calculated using the average lb-NOx/MWh published by TNRCC<sup>71</sup>.

The preliminary findings are shown in Table 4. For each county two simulations were performed using the appropriate weather file as indicated for the IECC climate zone, one simulation represented the average house that would have been built had the IECC/IRC code not been implemented<sup>72</sup>. The second simulation represents the energy use of an equivalent house built to IECC/IRC standards. The annual electricity savings/household, and peak day savings were then multiplied by the number of building permits to estimate the countywide savings for the projected houses to be built in 2002<sup>73</sup>. Next, an assumption was made about the Transmission and Distribution losses (T&D losses = 20%) to yield the total MWh savings per county. Then, the TNRCC lb-NOx/MWh factors<sup>74</sup> for the appropriate utility service district were applied<sup>75</sup> to allow for the estimation of

<sup>71</sup> This preliminary analysis does not include power transfers on the grid, and assumes transmission and distribution losses of 20%. Counties were assigned to utility service districts as indicated in .

<sup>72</sup> The characteristics for the average house followed the published survey data from the NAHB (2000).

<sup>73</sup> These projections were developed using linear averages of the published permits for each county.

<sup>74</sup> The lbs-NOx/MWh are those published in the TNRCC's June 5, 2002, Houston/Galveston Attainment Demonstration and Post-1999 Rate-of-Progress SIP, Appendix A: Description of the Methodology for Determining Credit for Energy Efficiency, Table 3.

<sup>75</sup> The application of the average TNRCC lb-NOx/MWh does not take into account the grid interaction between utility providers, which assumes all power was provided by each utility in their service area. A more accurate analysis, would take into account the grid-related power exchanges.

the potential NO<sub>x</sub> reductions from the calculated IECC/IRC reductions. As indicated, these lb-NO<sub>x</sub>/MWh can vary significantly from Reliant's 1.88 to TXU's 3.34 lb-NO<sub>x</sub>/MWh.

The estimated savings from implementing the IECC/IRC to the projected 91,632 new single-family units in the non-attainment and affected counties is 297,160 MWh/yr, which would result in 333.6 to 500.4 tons-NO<sub>x</sub>/yr, or 1.7 to 2.5 tons-NO<sub>x</sub>/peak-day. The cost associated with implementing the IECC/IRC is estimated to be \$500 per house<sup>76</sup>, which results in \$9.156 to \$13,734 \$/ton-NO<sub>x</sub>-yr, or \$14 to \$20 \$/ton-NO<sub>x</sub>-peak-day.

	County	Power Control Area <sup>1</sup>	Climate Zone <sup>2</sup>	No. of projects <sup>3</sup>	Floor Area (ft <sup>2</sup> ) <sup>4</sup>	1995 Average Energy Use (kWh) <sup>5</sup>	IECC 2001 Energy Use (kWh) <sup>6</sup>	Peak Date	1995 Peak Day (kW/1000 use) <sup>7</sup>	IECC Peak Day (kW/1000 House) <sup>8</sup>	Savings per house (kWh) <sup>9</sup>	Total Savings (MWh) 1995-IECC w/ 20% T&D Loss <sup>10</sup>	lb. NO <sub>x</sub> /MWh <sup>11</sup>	Total Savings			
														Tons/Year <sup>12</sup>	Tons/Day <sup>13</sup>	Peak Tons/Day <sup>14</sup>	
Affected County	Bastrop	ERCOT	4	146	2,426	16,546	13,310	31-Jul	77.98	59.56	3,235	966.77	2.68	0.7623	0.0021	0.0036	
	Bexar	San Antonio Public Service Bd	4	7,168	2,426	16,681	13,332	28-Aug	71.48	55.66	3,349	28,906.76	3.24	45.6659	0.1279	0.1637	
	Caldwell	ERCOT	4	101	2,426	16,546	13,310	31-Jul	77.98	59.56	3,235	392.09	2.68	0.5274	0.0014	0.0025	
	Comal	ERCOT	4	1,111	2,426	16,681	13,332	28-Aug	71.48	55.66	3,349	4,464.89	2.69	6.0653	0.0165	0.0236	
	Ellis	TXU	5	649	2,426	15,465	12,448	29-Jul	62.47	61.45	3,817	2,349.64	3.34	3.5039	0.0109	0.0229	
	Gregg	SWEPSCO	6	194	2,549	13,139	11,258	22-Jul	66.34	52.74	1,881	437.90	2.68	0.6670	0.0016	0.0033	
	Guadalupe	ERCOT	4	478	2,426	16,681	13,332	28-Aug	71.48	55.66	3,349	1,920.99	2.69	2.5837	0.0071	0.0102	
	Harrison	SWEPSCO	6	33	2,549	13,139	11,258	22-Jul	66.34	52.74	1,881	74.49	2.68	0.0959	0.0003	0.0006	
	Hays	ERCOT	5	737	2,426	16,662	13,180	31-Jul	76.03	60.26	3,502	3,097.12	2.69	4.1157	0.0114	0.0184	
	Johnson	TXU	5	629	2,426	15,465	12,448	29-Jul	62.47	61.45	3,817	2,377.23	3.34	3.6930	0.0104	0.0221	
	Kaufman	TXU	6	216	2,426	15,725	12,419	19-Aug	78.10	68.40	3,306	864.85	3.34	1.4443	0.0040	0.0072	
	Nueces	CRI	3	841	2,549	14,354	12,651	19-Aug	63.46	56.11	1,703	1,718.67	2.68	2.3039	0.0063	0.0093	
	Parker	TXU	6	302	2,426	15,725	12,419	19-Aug	78.10	68.40	3,306	1,198.09	3.34	2.0006	0.0055	0.0089	
	Rockwall	TXU	6	1,111	2,426	15,725	12,419	19-Aug	78.10	68.40	3,306	4,407.56	3.34	7.3606	0.0202	0.0366	
	Rusk	SWEPSCO	5	17	2,549	13,139	11,253	22-Jul	66.34	52.97	1,896	38.47	2.68	0.0516	0.0001	0.0003	
	San Patricio	CRI	3	210	2,549	14,254	12,651	19-Aug	63.46	56.11	1,703	445.50	2.68	0.5872	0.0016	0.0021	
	Smith	TXU	5	465	2,549	13,139	11,253	22-Jul	66.34	52.97	1,896	1,052.39	3.24	1.7575	0.0048	0.0086	
	Travis	Austin Energy	5	5,922	2,426	16,652	13,180	31-Jul	76.03	60.26	3,502	24,886.61	1.44	17.8184	0.0491	0.0791	
	Uptaper	SWEPSCO	6	17	2,549	13,139	11,253	22-Jul	66.34	52.74	1,881	38.37	2.68	0.0514	0.0001	0.0003	
	Victoria	CRI	3	166	2,549	13,229	12,264	1-5-Sep	67.35	60.21	1,672	313.00	2.68	0.4196	0.0011	0.0015	
	Williamson	TXU	5	4,111	2,426	16,652	13,180	31-Jul	76.03	60.26	3,502	12,376.07	2.68	23.1596	0.0634	0.1022	
	Wilson	ERCOT	4	16	2,426	16,651	13,332	28-Aug	71.48	55.66	3,349	64.30	2.68	0.0865	0.0002	0.0003	
Nonattainment County	Brazoria	Reliant Energy HL & P	3	2,006	2,549	13,740	11,859	29-Jul	66.52	56.958	1,881	4,532.46	1.68	4.2805	0.0117	0.0267	
	Chambers	EGS	4	216	2,549	12,913	11,297	1-5-Sep	59.02	49.96	1,616	616.67	2.68	0.8266	0.0023	0.0039	
	Collin	TXU	5	9,639	2,426	15,725	12,419	19-Aug	78.10	68.40	3,306	38,239.84	3.34	63.6605	0.1790	0.3172	
	Dallas	TXU	5	8,595	2,426	15,465	12,448	29-Jul	62.47	61.45	3,817	31,117.34	3.34	51.9660	0.1424	0.3017	
	Denton	TXU	6	5,336	2,426	15,725	12,419	19-Aug	78.10	68.40	3,306	21,176.91	3.24	35.2654	0.0969	0.1757	
	El Paso	EL PASO Electric Company	6	3,096	2,426	16,095	12,684	12-Jul	76.74	66.52	3,401	12,643.55	2.68	16.9437	0.0464	0.0899	
	Fort Bend	Reliant Energy HL & P	4	1,049	2,549	13,093	11,467	29-Jul	61.75	51.80	1,626	2,048.61	1.68	1.9240	0.0053	0.0098	
	Galveston	Reliant Energy HL & P	3	2,336	2,549	13,740	11,859	29-Jul	66.52	56.958	1,881	5,217.33	1.68	4.5907	0.0136	0.0241	
	Harris	EGS	4	19	2,549	12,913	11,297	1-5-Sep	59.02	49.96	1,616	36.64	2.68	0.0494	0.0001	0.0002	
	Harris	Reliant Energy HL & P	4	19,163	2,549	13,093	11,467	29-Jul	61.75	51.80	1,626	37,429.87	1.68	35.1841	0.0954	0.1795	
	Jefferson	EGS	4	610	2,549	12,913	11,297	1-5-Sep	59.02	49.96	1,616	1,162.91	2.68	1.5957	0.0043	0.0074	
	Liberty	EGS	4	213	2,549	12,913	11,297	1-5-Sep	59.02	49.96	1,616	413.05	2.68	0.6527	0.0016	0.0026	
	Montgomery	EGS	4	4,032	2,549	13,093	11,467	29-Jul	61.75	51.80	1,626	7,867.24	2.68	10.5460	0.0289	0.0539	
	Orange	EGS	4	172	2,549	12,913	11,297	1-5-Sep	59.02	49.96	1,616	333.54	2.68	0.4471	0.0012	0.0021	
	Tarrant	TXU	5	10,358	2,426	15,465	12,448	29-Jul	62.47	61.45	3,817	37,600.10	3.34	62.6252	0.1716	0.3636	
	Waller	Reliant Energy HL & P	4	22	2,549	13,093	11,467	29-Jul	61.75	51.80	2,047	54.04	1.68	0.0906	0.0001	0.0002	
	TOTAL												2,517	297,160.32		417.4296	1.1436

Table 4: NO<sub>x</sub> reduction potential from implementation of 2000 IECC/IRC in type A.1 residential buildings in non-attainment/affected counties.

<sup>76</sup> These costs are based on conversations with local building contractors and building officials in the Bryan/College Station area.



## 8 ISSUES & NEEDS

### 8.1 Funding / Expenditures.

With the current funding situation, the majority of the Laboratory efforts are in a minimal staff, reactionary mode responding to emergencies. The Laboratory is performing the following SB5 activities.

- Support training	On-going
- Quarterly Stakeholder meetings	On-going
- Respond to Municipal requests	On-going
- Respond to Builders, Manufacturers, Others	On-going
- Update Web, improve communications	On-going
- Support the TNRCC on the Emissions Reduction Reporting	due 6/15/02
- Release HERS rating format	due 9/1/02

In the General Appropriations Act, the Texas Engineering Experiment Station was appropriated \$1,363,060 for FY2002 and \$1,293,060 for FY 2003 out of the Texas Emission Reduction Plan Fund to perform the Laboratory's responsibilities under SB5. In December of 2001, the Comptroller announced that problems in collections existed and that only approximately \$58 million of the planned \$276 million would be collected over the first biennium. The Laboratory's budget was then projected to be reduced to approximately \$250,000 per year for the first two years. The Laboratory has currently received \$105,000 through April of 2002.

Funding is crucial in order for the Laboratory to fulfill its responsibilities under SB5. With funding, the Laboratory will produce over 100 targeted training sessions per year focused on specific groups. The Laboratory would then be able to respond and effectively work with municipalities to improve their code and above code modifications in a responsive manner. The Laboratory would then be able to work with manufacturers to make sure that they understand the impact of the codes to their product lines and help assure that the required products are on the market in a timely fashion.

### 8.2 Issues/Roadblocks Experienced on TERP

#### 8.2.1 Industry Concerns

The key roadblock has been the lack of funding. This ripples through all activities and creates situations where the Laboratory has to focus on emergencies. In general, the cooperation and enthusiasm of all parties (including the builders/builder groups, manufacturers, public interest groups and other agencies) has been very understanding and supportive.

This lack of adequate funding has seriously slowed the Laboratory's progress in making the code adaptation a smooth process in Texas. Builders are struggling with understanding the codes and also face liability issues that they do not fully understand. Manufacturers are faced with making large tooling investments and have numerous unanswered questions on specific code requirements that impact these investment decisions. State agencies are struggling with how to acquire and validate the needed data to build the required reports to EPA.

Many of the concerns noted by industry are included in other sections of this report. These include:

- o Duct insulation
- o Energy Star approvals
- o Home Energy Rating Systems
- o Effective dates for provisions of this legislation
- o Detailed code issues and conflicts

- Window issues
- Builder training and liability issues
- Code official ability to implement inspections
- Lack of programmatic funding to facilitate implementation

Cost and health impacts from the adoption of the codes have also arisen as a major issue. Cost impact needs to be studied and documented. In many cases, slight changes in construction methods can result in both cost savings and improved energy efficiency. Health is directly related to moisture in the inside air (and in the walls, etc) and tightness of the house. Improvements and higher skill in designing and installing mechanical cooling and heating equipment in residences will be required as the house becomes more efficient. The Laboratory needs to demonstrate and make these methods available to Texas builders.

### 8.2.2 Technology Concerns

As we go forward, methodologies will need to be developed for accurately reporting emission reductions. The Laboratory can determine the energy reductions in the municipalities and counties using a variety of methods. Ideally, we would like to have a "1-sheet" list of key code parameters on each building with its location. We will have the computer systems in place to then determine the location and quantify the energy reductions. Next, this hourly energy reduction profile needs to be tied to a particular power plant, which has specific operating conditions on NOx emissions. ERCOT data will be required for this. Finally, the reduction of hourly NOx output of the power plant needs to be put into an hourly atmospheric model (i.e., Ozone day or August-September 2000 Episode day) to determine the reduction in ozone. Although this description is overly-simplified, four groups must work closely together to accomplish this task. These are the Laboratory, TNRCC, ERCOT and the UT Atmospheric Sciences Group. This group can put a solid, defensible set of ozone reductions forward to the US EPA. The legislature could address how to allow these data to be acquired as truly needed. Deregulation of the electric utilities is also complicating the acquisition of needed data.

Additional work needs to be done in quantifying and demonstrating the cost associated with building to code standards. Cost will increase due to added insulation, higher efficiency windows, higher efficiency air-conditioners and other added items. Cost will decrease due to being able to down-size air-conditioners and furnaces and some other potential design changes like high efficiency ducts. Also, energy bills will decrease. "Back of the envelop" calculations show that the initial cost increase can be \$1,000 to \$2,000 or so, depending on what is done. A payback of under 3 to 5 years should be expected. Technologies are being developed to enable the first cost to be less than the old building methods, allow better comfort and improved energy efficiency. The Laboratory needs to participate in developing, demonstrating and training builders in these technologies and methods.

Along side of the cost issue is health. Homeowners are concerned with increased occurrence of asthma in children and other health related afflictions related to a "tighter" building. A tighter building can be a healthier building, if it is designed and maintained correctly. The Laboratory is ideally situated to provide the education and training on how to make the code adoption a major plus on improving the health of indoor environments.



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USGBC 2002. US Green Building Council, 110 Sutter Street, Suite410, San Francisco, CA 94101  
Telephone: (415) 445-9500 Fax: (415)445-9911

## 10 APPENDIX

## 10.1 Residential Builder's Guide.

Texas Residential Building Envelope Requirements											
Simplified Prescriptive Paths for Envelope compliance with the International Residential Code (IRC 2000)											
Glazing and Insulation						Foundation Type				Notes:	
Climate Zone	Path	Glazing			Ceiling	Wall					
		Area%	U-Factor	SHGC <sup>1</sup>			Basement Floor	Slab Wall	Crawl Space Perimeter		
<b>9</b> 4,000- 4,499 HDD <sup>3</sup>	1	15	.45	N/S	R-38	R-13	R-19	R-8	R-5, 2ft	R-11	
	2	20	.37	N/S	R-38	R-13	R-19	R-9	R-6, 2ft	R-13	
	3	25	.37	N/S	R-38	R-19	R-19	R-9	R-6, 2ft	R-13	
<b>8</b> 3,500- 3,999 HDD	1	15	.50	N/S	R-30	R-13	R-19	R-8	R-5, 2ft	R-10	
	2	20	.42	N/S	R-38	R-13	R-19	R-8	R-6, 2ft	R-10	
	3	25	.41	N/S	R-38	R-19	R-19	R-8	R-6, 2ft	R-10	
<b>7</b> 3,000- 3,499 HDD	1	15	.55	.40	R-30	R-13	R-19	R-7	<sup>2</sup> R-4, 2ft	R-8	
	2	20	.46	.40	R-38	R-13	R-19	R-7	R-0	R-8	
	3	25	.45	.40	R-38	R-19	R-19	R-7	R-0	R-8	
<b>6</b> 2,500- 2,999 HDD	1	15	.60	.40	R-30	R-13	R-19	R-6	<sup>2</sup> R-4, 2ft	R-7	
	2	20	.50	.40	R-38	R-13	R-19	R-6	R-0	R-7	
	3	25	.46	.40	R-38	R-16	R-19	R-6	R-0	R-7	
<b>5</b> 2,000- 2,499 HDD	1	15	.65	.40	R-30	R-13	R-11	R-5	R-0	R-6	
	2	20	.52	.40	R-38	R-13	R-11	R-5	R-0	R-6	
	3	25	.50	.40	R-38	R-13	R-19	R-5	R-0	R-10	
<b>4</b> 1,500- 1,999 HDD	1	15	.75	.40	R-26	R-13	R-11	R-5	R-0	R-5	
	2	20	.60	.40	R-30	R-13	R-11	R-5	R-0	R-5	
	3	25	.52	.40	R-30	R-13	R-13	R-6	R-0	R-6	
<b>3</b> 1,000- 1,499 HDD	1	15	.75	.40	R-19	R-11	R-11	R-0	R-0	R-5	
	2	20	.70	.40	R-30	R-13	R-11	R-0	R-0	R-5	
	3	25	.55	.40	R-30	R-13	R-11	R-0	R-0	R-5	
<b>2</b> 500- 999 HDD	1	15	.90	.40	R-19	R-11	R-11	R-0	R-0	R-4	
	2	20	.75	.40	R-30	R-13	R-11	R-0	R-0	R-4	
	3	25	.65	.40	R-30	R-13	R-11	R-0	R-0	R-4	

<sup>1</sup>N/S means "not specified". Calculations done using IECC Chap. 4 use a SHGC of .58 for the standard case.

<sup>2</sup>The map in IRC Figure R301.2(6) indicates that parts of Texas qualify as areas of "very heavy" winter insulation probability. Under an exception in the IRC, the slab perimeter insulation requirement in this path may be avoided. To make use of this exception and still comply with the Code, a builder must use IECC Section 502.2.1.4, IECC Section 502.2.4, or IECC Chapter 4, instead of this path.

<sup>3</sup>HDD = Heating Degree Days

1. This table of building envelope requirements is based upon the 2000 International Residential Code (IRC), published by the International Code Council.
2. The IRC prescriptive requirements are applicable to homes with glazing areas of 15% and below. For homes designed with glazing areas greater than 15%, the IRC incorporates the International Energy Conservation Code (IECC) by reference, which contains additional prescriptive and performance-related compliance alternatives.
3. Source of requirements: 2000 IRC, Ch. 11 (up to 15% only) and 2000 IECC, Ch. 5, Prescriptive Packages for Climate Zones 2-9.
4. Window area %, U-factor, and SHGC are maximum acceptable levels.
5. Insulation R-values are minimum acceptable levels.
6. Applies to single-family, wood-frame residential construction only. For mass wall construction, see IRC Section N1102.1.1.1; for steel-framed walls, see IRC Section N1102.1.1.2.
7. "Glazing" refers to any translucent or transparent material in exterior openings of buildings, including windows, skylights, sliding glass doors, the glass areas of opaque doors, and glass block.
8. Fenestration product (window, door, glazing) U-factor and SHGC must be determined from a National Fenestration Rating Council (NFRC) label on the product, or obtained from default tables (IECC Table 102.5.2(3) in Chapter 1).
9. Glazing area % is the ratio of the area of the rough opening of windows to the gross wall area, expressed as a percentage. Up to one percent of the total window area may be exempt from the U-factor requirement.
10. Opaque doors are not considered glazing (or "windows") and must have a maximum U-factor of 0.35. One exempt door allowed.
11. Infiltration requirements: Windows ≤ 0.30 cfm per sq.ft. of window area; doors ≤ 0.30 cfm per sq.ft. of door area (swinging doors below 0.50 cfm); determined in accordance with AAMA/WDMA 101/I.S.2 (must be tested and labeled in accordance with ASTM E 283).
12. R-2 shall be added to the requirements for slab insulation where uninsulated hot water pipes, air distribution ducts or electric heating cables are installed in or under the slab.
13. Floors over outside air must meet ceiling insulation requirements.
14. R-values for walls represent the sum of cavity insulation plus insulated sheathing, if any.
15. Prescriptive packages are based upon meeting or exceeding minimum equipment efficiencies for HVAC and water heating (IECC Table 503.2).

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Figure 46: Example of the Laboratory's Builder's Guide available for distribution via the web and on laminated cardstock (page 1).

# Texas Residential Building Guide to Energy Code Compliance

## International Residential Code (IRC 2000) and International Energy Conservation Code (IECC 2000)

International Residential Code and International Energy Conservation Code as of May 1, 2001

Texas Edition 2001, Revision 001

### How to Use This Guide

This guide contains eight color-coded climate zones (numbers 2 through 9) designed to simplify determination of the envelope requirements of the International Residential Code (IRC 2000, Chapter 11) or the International Energy Conservation Code (IECC 2000) for Texas. Refer to the IRC 2000 or IECC 2000 for a complete description of all the requirements and compliance alternatives. Local requirements may also vary. Each county is assigned to one of the eight zones, which vary according to the different climate zones in Texas.

### Step-by-Step Instructions

1. Use the color-coded map to locate the county in which the construction or remodeling is taking place and find the climate zone (2 through 9) associated with that county.
2. Use the "Table of Building Envelope Requirements" (on the back of this sheet) to find the set of construction options or "paths" associated with the climate zone selected above. Each path describes an acceptable combination of envelope components based on percent glazed area.
3. Review the paths and select the one most suited to your project.
4. Construct or remodel the building according to the selected path and comply with basic code requirements, which include:
  - a. installing components to restrictions from Mfr.
  - b. determining load capabilities to list the properly sized HVAC equipment
  - c. meeting minimum equipment efficiency requirements for HVAC, water heating and other motors
  - d. providing prescriptive make-up air intake
  - e. installing temperature controls
  - f. limiting window and door leakage
  - g. caulking or sealing joints, gaps and penetrations
  - h. installing vapor retarders where required
  - i. sealing and insulating ducts (No ducts placed above)
  - j. installing pipes properly

### Texas Counties by Climate Zones

Use the color-coded map of Texas to locate a county. The reverse side of this form shows three prescriptive paths for the selected Climate Zone.

#### 9 4,000 - 4,499 HDD

Armstrong	Hasford	Oldham
Bailey	Hartley	Panther
Carson	Hempill	Potter
Castro	Hitchcock	Randall
Dallam	Lubbock	Robert
Deaf Smith	Mohr	Sterling
Gray	Ochiltree	Wheeler

HDD = Heating Degree Days

#### 4 1,500 - 1,999 HDD

Austin	Grimes	Moran
Bastrop	Gradidge	Montgomery
Beauregard	Harris	Orange
Brazos	Harris	Robertson
Brewster	Jefferson	San Jacinto
Caldwell	Killeen	Val Verde
Chambers	Lambert	Waller
Colorado	Lee	Wesley
Comal	Liberty	Wichita
Fayette	Madison	Wichita
Fort Bend	Medina	Wilson
Goizales		

#### 8 3,500 - 3,999 HDD

Blincoe	Hall
Cochran	Hockley
Dowley	Lamb
Floyd	Sulphur
Hale	Yockum

HDD = Heating Degree Days

#### 3 1,000 - 1,499 HDD

Amarillo	Galveston	McMullen
Aransas	Goliad	Nueces
Bee	Jackson	Rehoboth
Brazoria	Jim Wells	San Antonio
Calhoun	Karnes	Victoria
DeWitt	La Salle	Wichita
Dimmit	Lisa Oak	Wilbourn
Duval	Maricopa	Zavala
Frio	Martinez	

#### 7 3,000 - 3,499 HDD

Anchor	Dike	Lytle
Bayard	Foard	Mohr
Borden	Gaines	Scott
Childress	Garza	Stonewall
Clay	Hartman	Terry
Collingsworth	West	Wichita
Cottle	King	Wilder
Crosby	Knox	
Dawson	Lubbock	

HDD = Heating Degree Days

#### 2 500 - 999 HDD

Brooks	Jim Hogg	Starr
Cameras	Kelly	Wichita
Chadwick	Kernberg	Zapata

#### 5 2,000 - 2,499 HDD

Anderson	Henderson	Pecos
Angelika	Hill	Polk
Bandera	Hood	Presidio
Bell	Houston	Reagan
Brewster	Irion	Real
Brewster	Jasper	Ritvik
Brown	Julesburg	Rusk
Brown	Madison	Sabine
Brown	Marshall	Saltwater
Cherokee	Kimble	San Saba
Comal	Lampasas	Schlesinger
Comstock	Lea	Sibley
Cochran	Lincoln	Smith
Conell	Lisa	Somerville
Craig	Marion	Stonewall
Crockett	Mohr	Tarrant
Dallas	Mohr	Terrell
Edwards	Moran	Tom Green
Ellis	Mills	Travis
Falls	Nacogdoches	Trinity
Freesburg	Nauvoo	Tyler
Gillespie	Newton	Upton
Hamilton	Panola	Williamson
Hays		

#### 6 2,500 - 2,999 HDD

Andrews	Gregg	Palo Pinto
Bowie	Harrison	Parker
Callahan	Haskell	Rails
Camp	Hopkins	Red River
Cass	Howard	Reeves
Coke	Hudspeth	Rockwall
Collins	Hunt	Stackhouse
Cooper	Jack	Stephens
Cotton	Jeff Davis	Stirling
Delta	Joel	Taylor
DeWitt	Karnes	Tyler
Eastland	Lamar	Upton
Edwards	Loving	Van Zandt
El Paso	Marion	Ward
Erath	Martin	Wheeler
Fannin	Mitchell	Wheeler
Fisher	Mitchell	Wheeler
Franklin	Montague	Wheeler
Glasscock	Morris	Yockum
Grayson	Nolan	

### Energy Systems Lab - Texas A&M University

http://www.esl-sb5.edu/

Figure 47: Example of the Laboratory's Builder's Guide available for distribution via the web and on laminated cardstock (page 2).



## 10.2 Code Compliance Form for Residential Areas.

# Texas Building Energy Efficiency Code Compliance Form For Residential Buildings in Unincorporated Areas

Effective Date: 9/1/2002

Texas law requires the person building a new residential structure to comply with the Texas Building Energy Efficiency Code (International Residential Code ("IRC") and/or International Energy Conservation Code ("IECC") as it existed on May 1, 2001) pursuant to Health and Safety Code Section 388.003 (single or multifamily units, three floors and under).

Common Address or Legal Description: \_\_\_\_\_  
County: \_\_\_\_\_

This residence (select one of the following options):

- ☐ 1. Has been compliance certified by a national, state, or local accredited energy efficiency program;
- ☐ 2. Has been compliance certified from a private code-certified inspector using the IRC's Energy Efficiency Chapter (Chapter 11) or the IECC; or
- ☐ 3. Has been built to include the following energy efficiency elements: (If this option is selected, complete the following 5 categories and provide any additional necessary information)

**(1) Insulation values (R-value of insulation installed) for each of the following:**

Framing material (check one): Wood    Steel    Mass Wall    or Other (specify): \_\_\_\_\_

Attic .....(R-value) \_\_\_\_\_

Cathedral ceiling .....(R-value) \_\_\_\_\_

Opaque walls .....(R-value) \_\_\_\_\_ Floors over unheated spaces .....(R-value) \_\_\_\_\_

Floors over outside air .....(R-value) \_\_\_\_\_ Ducts (outside conditioned space (R-value) \_\_\_\_\_

Foundation type: Slab-on-grade .....(R-value) \_\_\_\_\_ (Depth): \_\_\_\_\_

Crawlspace .....(R-value) \_\_\_\_\_ (Depth): \_\_\_\_\_

Basement (R-value, if applicable): \_\_\_\_\_ (Depth): \_\_\_\_\_

(Interior/Exterior): \_\_\_\_\_

Percent of basement walls underground \_\_\_\_\_ % Area of "very heavy termite infestation" (yes/no)

**(2) Ratings of windows and doors for each of the following:**

Glazing area percentage: \_\_\_\_\_ %

(ratio of the area of the rough opening of glazing to the gross wall area)

Glazed door(s) (sliding or hinged) .....(U-factor) \_\_\_\_\_ (SHGC) \_\_\_\_\_

Other exterior doors .....(U-factor) \_\_\_\_\_ (SHGC) \_\_\_\_\_

Windows (determined from NFRC rating):

(U-factor) \_\_\_\_\_

(SHGC) \_\_\_\_\_

(Air Infiltration) \_\_\_\_\_

**(3) HVAC equipment efficiency levels:**

Heating systems: Gas fired forced air furnace .....(AFUE rating) \_\_\_\_\_

Electric heat pump .....(HSPF rating) \_\_\_\_\_

Version 1.0, November 20, 2001

Page 1 of 2

Figure 48: Example of the Laboratory's self-certification form for code compliance in unincorporated areas (front).

# Texas Building Energy Efficiency Code Compliance Form For Residential Buildings in Unincorporated Areas

Effective Date: 9/1/2002

Air conditioning systems: Electric unit ..... (SEER rating) \_\_\_\_\_  
Electric heat pump ..... (EER rating) \_\_\_\_\_  
Ground source heat pump ..... (EER rating) \_\_\_\_\_

(4) Water heating efficiency levels: Water heater fuel type .....  
 Water heater capacity .....  
 NAECA energy factor .....

**(5) Basic requirements** (check to indicate the measures you have completed or write "N/A" if in applicable):

Air-tight recessed lights (ASTME 283): \_\_\_\_\_ U.L. 181 duct sealing products (or mastics): \_\_\_\_\_  
Air sealed penetrations/gaps/holes, etc.: \_\_\_\_\_ Shower heads rated at 2.5gpm/80psi: \_\_\_\_\_  
HVAC piping insulation: \_\_\_\_\_ Circulating hot-water piping insulation: \_\_\_\_\_  
Multi-family units separately metered: \_\_\_\_\_ Thermostats for each system: \_\_\_\_\_  
Heat pump thermostat: \_\_\_\_\_ Equipment maintenance information: \_\_\_\_\_  
Vapor retarders: \_\_\_\_\_ (where installed: \_\_\_\_\_)

**Additional Information:** (attach additional sheet if necessary)

**Complete the following Certification, as applicable:**

Accredited energy efficiency program: \_\_\_\_\_

**Inspector name/address:** \_\_\_\_\_

Inspector certified by: \_\_\_\_\_ Certification number: \_\_\_\_\_

**Builder or Seller name/address:** .....

**Builder or Seller signature:** \_\_\_\_\_ **Date:** \_\_\_\_\_

Buyer signature(s): \_\_\_\_\_ Date: \_\_\_\_\_

Inspector signature: ..... Date:

*This form may be reproduced-Form available from: Texas A&M University Energy Systems Laboratory, Weisenbaker Hall, College Station, Texas; or on the Internet at <http://www-esl.tamu.edu/index.html>*

Telephone: (979) 862-2775. Facsimile (979) 862-8687

Version 1.0, November 20, 2001

Page 1 of 2

Figure 49: Example of the Laboratory's self-certification form for code compliance in unincorporated areas (back).



10.3 Senator Brown's Letter of Intent Regarding R8 Flex Duct.

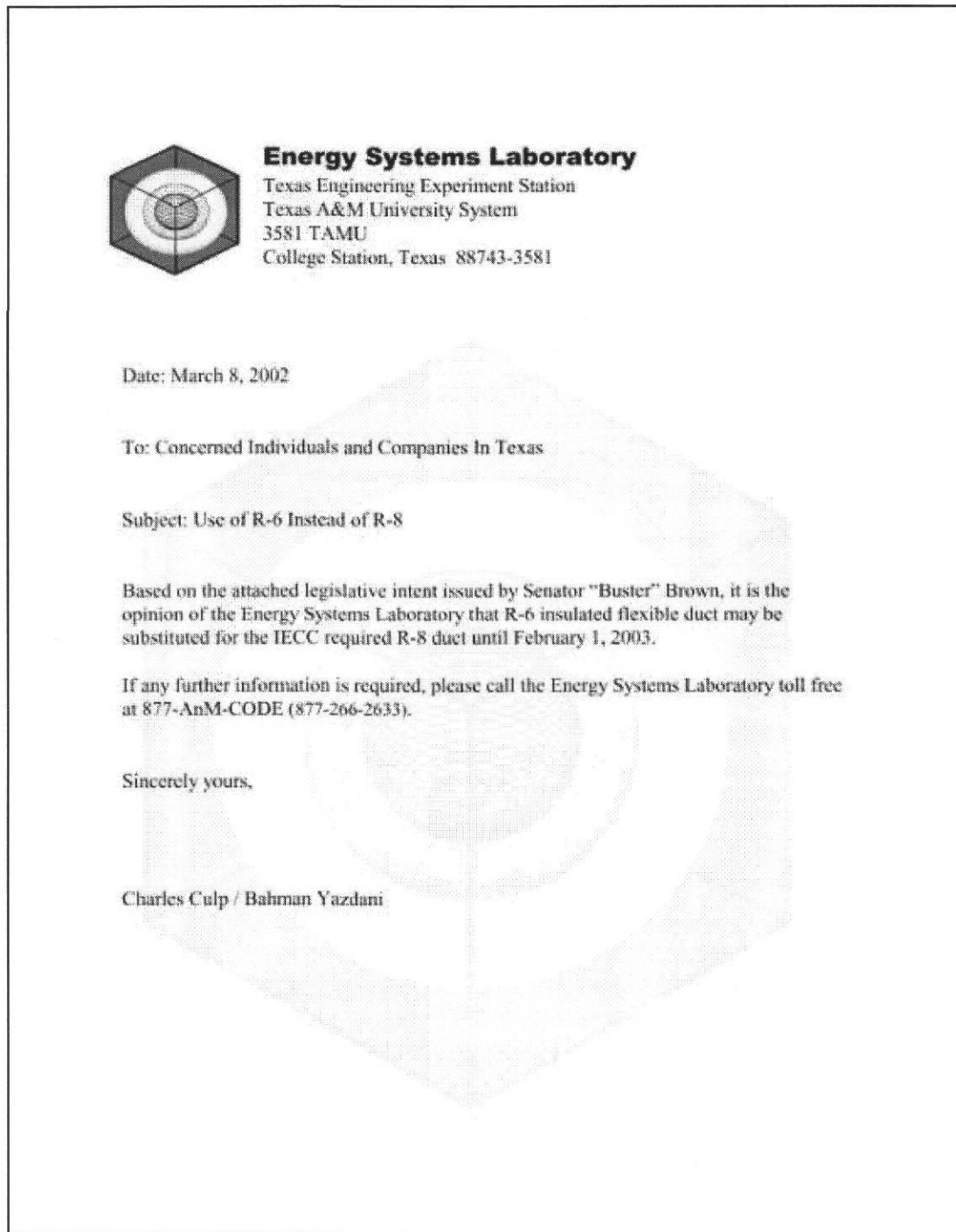


Figure 50: Laboratory's letter to builders regarding the R8 flexible duct issue (page 1).

March 1, 2002

Charles Culp, P.E., Ph.D. & Bahman Yazdani, P.E.  
Associate Directors, Energy Systems Lab  
Texas Engineering Experiment Station  
Texas A&M University  
214 Wisenbaker Engineering Res. Ctr.  
3581 TAMU  
College Station, TX 77843-3581

Re: Legislative intent for use of R8 flexible duct

Dear Dr. Culp & Mr. Yazdani:

Please allow this letter to serve as a written statement of my legislative intent regarding the implementation date for the required use of R8 flexible duct as stated in Senate Bill 5, 77<sup>th</sup> Legislature. The intended date for use of R8 flexible duct is February 1, 2003.

An exception to use R6 insulated duct in lieu of the R8 duct code requirement should be allowed for until February 1, 2003. This should help clarify confusion when R6 duct is used within the existing code requirements until that date.

The following scientific-based explanations provided by your technical staff at the Texas A&M University Energy Systems Laboratory (TAMU ESL) give further support to the intended date of compliance for all communities within Texas:

The International Energy Conservation Code (IECC) of 2001 requires that R8 flexible duct be used in place of lower R-rated insulated duct, when ducts are in unconditioned spaces. Although R6 duct is widely and economically available, R8 insulated flexible duct is not at this time. Limited supplies are available from one manufacturer but not in the quantities needed to satisfy the

Figure 51: Senator Brown's letter to the Laboratory regarding the R8 flexible duct issue (page 1).

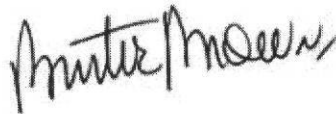
requirements for the homes in municipal areas.

Chapter 11 of the International Residents Code (IRC) code specifically allows R5 or higher in homes with up to 15% window to wall area. The IECC requires R8 for above 15% window to wall area. Situations where code inspectors have not allowed R6 duct in housing where the window to wall area is under 15% have been reported, undoubtedly due to confusion and inadequate training.

Technically, R6 insulated flexible duct causes minimal decrease in efficiency except when used in unconditioned attics. Use of R6 duct will result in a few percent loss of efficiency for the cooling system. Improper installation of either R6 or R8 that causes leakage will result in a much greater loss of system efficiency.

As the author of Senate Bill 5, I am also requesting that the TAMU ESL expand the focus of the code training workshops to cover additional detail on the correct installation of this duct, and that the TAMU ESL survey and work with flexible duct manufacturers to prepare to deliver the needed quantities of R8 duct at competitive prices over the next seven months then report to the Senate Natural Resources Committee by September 1, 2002.

Sincerely,



JEB:ww

cc: Texas Association of Builders  
Texas Association of General Contractors  
Associated General Contractors

Figure 52: Senator Brown's letter to the Laboratory regarding the R8 flexible duct issue (page 2).

#### 10.4 Proposed NTCOG Amendments to the 2000 IECC.

-----Original Message-----

From: Jennifer Crosby [mailto:jcrosby@dfwinfo.com]

Sent: Monday, March 18, 2002 4:18 PM

To: 'Al Godwin' (E-mail); Bill Elliott (E-mail); Charles Bloomberg (E-mail); David Session (E-mail); Dennis Pitts (E-mail); Ed Dryden (E-mail); Jack Craycroft (E-mail); Jack Thompson (E-mail); 'James Johns' (E-mail); Jim Olk (E-mail); 'Joe Pierce' (E-mail); Karen Makarem (E-mail); Larry King (E-mail); Leo Stambaugh (E-mail); Mark Hightower (E-mail); Ravi Shah (E-mail); Robert Younger (E-mail); Ronnie Frazier (E-mail); Russ Mower (E-mail); Scott Williams (E-mail); Si McHugh (E-mail); Tim Dovel (E-mail); Tom Fitzpatrick (E-mail); Tom Smith (E-mail); Tommy Jackson (E-mail)

Cc: Kenny Calhoun

Subject: Response Requested - Energy Amendment Revisions

To the Building & Energy Advisory Board:

Please review the minor revisions made in the attached Amendments to the 2000 IECC and Chapter 11 of the 2000 IRC. These revisions were made based on comments received from the Energy Systems Laboratory in January (please see <http://www.dfwinfo.com/envir/coordinated/regcodes/2001Amend/ESLresponse.html> for full text of the ESL's comments).

Please vote on whether or not you approve of these revisions by responding to this email by 12:00 PM Friday, March 22. The changes require approval from a minimum of 2/3 of the board to be instituted.

Summary of Revisions:

- \* Chapter 11 of the IRC - one change on page 2
- \* IECC - two changes on page 2

If you have any questions, please contact me. Thanks!

<<2000 IRC amendments-Chapter 11 ESL.doc>> <<2000 IECC amendments ESL.doc>>

Jenny Crosby

Environmental Planner

North Central Texas Council of Governments

P.O. Box 5888 Arlington, TX 76005-5888

Voice: 817-695-9108 Fax: 817-695-9191

---

Recommended Amendments to the  
2000 International Energy Conservation Code  
North Central Texas Council of Governments region

**\*\*Section 101.3; amend as follows:**

101.3 Compliance. Compliance with this code shall be determined in accordance with Sections 101.3.1, ~~and 101.3.2~~, or 101.3.3.

**\*\*Add the following item:**

101.3.3. Alternative compliance. A building certified through a voluntary energy performance testing program approved as meeting or exceeding the provisions of this code may be deemed to comply with the requirements of this code.

(Reason: This amendment would encourage participation in above-code programs and provide an attractive alternative path for unconventional builders who are committed to quality and efficiency, but concerned about mechanics of code compliance. NCTCOG will arrange advisory review of such programs.)

---

**\*\*Section 302.1; Replace blank Table 302.1 Exterior Design Conditions with the following:**

CONDITION	VALUE
Winter <sup>a</sup> , design dry-bulb (°F) (99.6%)	17
Summer <sup>a</sup> , design dry-bulb (°F) (0.4%)	100
Summer <sup>a</sup> , design wet-bulb (°F) (0.4%)	78
Degree days heating <sup>b</sup>	2407
Degree days cooling <sup>b</sup>	2603
Climate zone <sup>c</sup>	5B

**\*\*Delete note "a" and replace with the following:**

a. These values are from ASHRAE Handbook of Fundamentals for Dallas/Ft. Worth International Airport 99.6% Winter DB, 0.4% Summer DB, and 0.4% Summer WB; and from Local Climatological Data for Dallas-Ft. Worth published by the National Climatic Data Center, National Oceanic and Atmospheric Administration. These values are for the purpose of providing a uniform basis of requirements for North Central Texas. This will not preclude licensed professionals from submitting design analyses based on site measurements or published data more specific to the building site. Adjustments shall be permitted to reflect local climates which differ from the tabulated values, or local weather experience determined by the code official.

(Reason: One of the references in note "a" is in error. The 1997 ASHRAE Handbook of Fundamentals no longer publishes the design temperature tables in the format assumed by this reference. The main purpose of this change, however, is to provide typical design data for the NCTCOG region for ease of reference within this code.)

---

**\*\*Delete Figures 302.1 (1-43, 45-51).**

(Reason: There is no need to reference the maps of other states.)

---

**\*\*Section 502.1.1; delete exception #2 and substitute the following:**

2. Buildings located in Climate Zones 5 through 6 as indicated in Table 302.1.

(Reason: This would eliminate the requirement of a vapor retarder throughout the NCTCOG region. Eliminating vapor retarders in hot and humid climate zones is consistent with the recommendation of most building scientists.)

**\*\*Section 502.1.5; add the following exceptions:**

Exceptions:

1. Any glazing facing within 45 degrees of true north;
2. Any glazing facing within 45 degrees of true south which is shaded along its full width by a permanent overhang with a projection factor of 0.3 or greater.
3. Any fenestration with attached screens where the screens have a rated shading coefficient of .6 or less.

(Reason: This will allow north facing windows, which do not receive direct solar radiation, to be exempt from the minimum SHGC requirement; provides a simple way for south facing windows to effectively achieve summer shade and still receive some solar heat benefit in winter; and specifically allows use of solar screens to achieve the shading effect.)

**\*\*Section 502.2; Replace blank Table 502.2 Heating & Cooling Criteria with the following:**

Table 502.2<sup>ag</sup>

HEATING AND COOLING CRITERIA

Element	Mode	Type A-1 Residential Buildings U <sub>o</sub>	Type A-2 Residential Buildings U <sub>o</sub>
Walls	Heating or cooling	0.15	0.22
Roof/ceiling	Heating or cooling	0.03	0.03
Floors over unheated spaces	Heating or cooling	0.05	0.05
Heated slab on grade	Heating	R-value = 6	R-value = 6
Unheated slab on grade	Heating	R-value = 0	R-value = 0
Basement wall	Heating or cooling	U-factor = 0.15	U-factor = 0.15
Crawl space wall	Heating or cooling	U-factor = 0.15	U-factor = 0.15

**\*\*Delete Note "a" and replace with the following:**

a. The above values have been determined for all counties in the North Central Texas Council of Governments region.

**\*\*Add Note "g":**

g. These requirements apply only to the boundaries of conditioned space. Air conditioning equipment and ductwork is recommended, but not required, to be located within the conditioned space in North Central Texas zones.

**\*\*Delete Figures 502.2(1-6)**

(Reason: This change unifies the requirements for all counties within the North Central Texas COG. Reference to the graphs is no longer needed when the values have been specified.)

**\*\*Section 502.2; Add note to Fig 502.2(7):**

All counties within the North Central Texas Council of Governments region are designated as within the area of very heavy termite infestation probability for purpose of uniform interpretation of this requirement.

(Reason: This allows for uniform interpretation of the map throughout the area of the COG.)

**\*\*Section 502.2.4; Delete prescriptive Tables 502.2.4(1-9) and substitute the following:**

**\*\*Replace Tables 502.2.4 (1-6) with:**

**Table 502.2.4(1)**

Prescriptive Building Envelope Requirements, Type A-1 Residential Buildings, Based on Window Area as a Percent of Gross Exterior Wall Area (for zones 5b and 6b)

% Glazing	Maximum	Minimum					
	Glazing U-factor	Ceiling R-value	Exterior wall R-value	Floor R-value	Basement wall R-value	Slab perimeter R-value and depth	Crawl space wall R-value
<8%	0.70	R-26	R-11	R-11	R-5	R-0	R-6
<12%	0.65	R-26	R-13	R-11	R-5	R-0	R-5
<15%	0.65	R-30	R-13	R-11	R-6	R-0	R-7
<18%	0.52	R-30	R-13	R-19	R-6	R-0	R-7
<20%	0.50	R-38	R-13	R-19	R-6	R-0	R-7
<25%	0.46	R-38	R-16	R-19	R-6	R-0	R-7

**\*\*Replace Tables 502.2.4 (7-9) with:**

**Table 502.2.4(2)**

Prescriptive Building Envelope Requirements, Type A-2 Residential Buildings, Based on Window Area as a Percent of Gross Exterior Wall Area

% Glazing	Maximum	Minimum					
	Glazing U-factor	Ceiling R-value	Exterior wall R-value	Floor R-value	Basement wall R-value	Slab perimeter R-value and depth	Crawl space wall R-value
<20%	0.55	R-30	R-13	R-11	R-5	R-0	R-6
<25%	0.55	R-30	R-13	R-11	R-5	R-0	R-5
<30%	0.47	R-38	R-13	R-19	R-7	R-0	R-8

(Reason: This change a) reduces the number of tables to be referenced; b) unifies envelope prescriptive requirements across all areas within the COG, requiring the more restrictive values of zones 5b or 6b; and c) eliminates slab edge insulation requirement.)

**\*\*Section 503.3.3.3; amend as follows:**

All supply and return-air ducts and plenums installed as part of an HVAC air-distribution system shall be thermally insulated in accordance with Table 503.3.3.3 or where such ducts or plenums operate at static pressures greater than 2 in. w.g. (500 Pa) in accordance with Section 503.3.3.4.1.

(Reason: This change clarifies that requirements for higher pressure ducts are given elsewhere. These duct systems are typically associated with commercially sized equipment. This change will be included in the IECC 2001 Supplement.)

**\*\*Section 503.3.3.4; amend subsections as follows:**

503.3.3.4.1 High- and medium-pressure duct systems. All ducts and plenums operating at static pressures greater than 2 in. w.g. (500 Pa) shall be insulated and sealed in accordance with Section 803.2.8. ~~High pressure and medium pressure~~ Ducts operating at static pressures in excess of 3 in. w.g. (750 Pa) shall be leak tested in accordance with ~~SMACNA HVAC Air Duct Leakage Test Manual with a rate of air leakage not to exceed the maximum rate specified in that standard.~~ Section 803.3.6. Pressure classifications



specific to the duct system shall be clearly indicated on the construction documents in accordance with the International Mechanical Code.

503.3.3.4.2 Low pressure duct systems. All longitudinal and transverse joints, seams and connections of ~~low pressure~~ supply and return ducts operating at static pressures less than or equal to 2 in. w.g. (500 Pa) shall be securely fastened and sealed with welds gaskets, mastics (adhesives), mastic-plus-embedded fabric systems or tapes installed in accordance with the manufacturer's installation instructions. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the International Mechanical Code.

{Exception is unchanged}

(Reason: These changes, which will be included in the 2001 Supplement to the IECC, are necessary because the term "low" and "high" have been discontinued by SMACNA. The modification more clearly delineates the static pressure classification of duct systems in question.)

---

\*\* Section 802.2; Replace blank tables 802.2 (1-4) with the completed tables provided on the following four pages. Delete tables 802.2 (5-37).

(Reason: This change provides a unified set of prescriptive requirements for all areas within the NCTCOG area based upon the most restrictive zone's requirements (5b or 6b). The deleted tables are not necessary after tables 1-4 are completed, and eliminates data irrelevant to the NCTCOG region.)

TABLE 802.2(1)  
BUILDING ENVELOPE REQUIREMENTS

WINDOW AND GLAZED DOOR AREA 10 PERCENT OR LESS OF ABOVE-GRADE WALL AREA			
ELEMENT	CONDITION/VALUE (Zones 5B,6B)		
Skylights (U-factor)	1		
Slab or below-grade wall (R-value)	R-0		
Windows and glass doors	SHGC	U-factor	
PF < 0.25	Any	Any	
0.25 < PF < 0.50	Any	Any	
PF > 0.50	Any	Any	
Roof assemblies (R-value)	Insulation between framing	Continuous insulation	
	R-19	R-16	
All-wood joist/truss	R-25	R-17	
Metal joist/truss	NA	R-16	
Concrete slab or deck	R-25	R-17	
Metal purlin with thermal block	X	R-17	
Metal purlin without thermal block			
Floors over outdoor air or unconditioned space (R-value)	Insulation between framing	Continuous insulation	
	R-11	R-6	
All-wood joist/truss	R-11	R-6	
Metal joist/truss	NA	R-6	
Concrete slab or deck			
Above-grade walls (R-value)	No framing	Metal framing	Wood framing
Framed			
R-value cavity	NA	R-11	R-11
R-value continuous	NA	R-0	R-0
CMU, > 8 in., with integral insulation			
R-value cavity	NA	R-0	R-0
R-value continuous	R-0	R-0	R-0
Other masonry walls			
R-value cavity	NA	R-0	R-0
R-value continuous	R-0	R-0	R-0

TABLE 802.2(2)  
BUILDING ENVELOPE REQUIREMENTS

WINDOW AND GLAZED DOOR AREA OVER 10 PERCENT BUT NOT GREATER THAN 25 PERCENT OF ABOVE-GRADE WALL AREA			
ELEMENT	CONDITION/VALUE		
Skylights (U-factor)	1		
Slab or below-grade wall (R-value)	R-0		
Windows and glass doors PF < 0.25 0.25 < PF < 0.50 PF > 0.50	SHGC	U-factor	
	0.6	Any	
	0.7	Any	
	Any	Any	
Roof assemblies (R-value)	Insulation between framing	Continuous insulation	
	R-25	R-19	
	R-25	R-20	
	NA	R-19	
	R-30	R-20	
	X	R-20	
Floors over outdoor air or unconditioned space (R-value)	Insulation between framing	Continuous insulation	
	R-11	R-6	
	R-11	R-6	
	NA	R-6	
Above-grade walls (R-value)	No framing	Metal framing	Wood framing
Framed			
R-value cavity	NA	R-11	R-11
R-value continuous	NA	R-0	R-0
CMU, > 8 in., with integral insulation			
R-value cavity	NA	R-11	R-11
R-value continuous	R-5	R-0	R-0
Other masonry walls			
R-value cavity	NA	R-11	R-11
R-value continuous	R-5	R-0	R-0

TABLE 802.2(3)  
BUILDING ENVELOPE REQUIREMENTS

WINDOW AND GLAZED DOOR AREA OVER 25 PERCENT BUT NOT GREATER THAN 40 PERCENT OF ABOVE-GRADE WALL AREA			
ELEMENT	CONDITION/VALUE		
Skylights (U-factor)	1		
Slab or below-grade wall (R-value)	R-0		
Windows and glass doors PF < 0.25 0.25 < PF < 0.50 PF > 0.50	SHGC	U-factor	
	0.4	0.7	
	0.5	0.7	
	0.6	0.7	
Roof assemblies (R-value)  All-wood joist/truss Metal joist/truss Concrete slab or deck Metal purlin with thermal block Metal purlin without thermal block	Insulation between framing	Continuous insulation	
	R-25	R-19	
	R-25	R-20	
	NA	R-19	
	R-30	R-20	
	X	R-20	
Floors over outdoor air or unconditioned space (R-value) All-wood joist/truss Metal joist/truss Concrete slab or deck	Insulation between framing	Continuous insulation	
	R-11	R-6	
	R-11	R-6	
	NA	R-6	
Above-grade walls (R-value)	No framing	Metal framing	Wood framing
Framed			
R-value cavity	NA	R-11	R-11
R-value continuous	NA	R-0	R-0
CMU, > 8 in., with integral insulation			
R-value cavity	NA	R-11	R-11
R-value continuous	R-5	R-0	R-0
Other masonry walls			
R-value cavity	NA	R-11	R-11
R-value continuous	R-5	R-0	R-0

TABLE 802.2(4)  
BUILDING ENVELOPE REQUIREMENTS

WINDOW AND GLAZED DOOR AREA OVER 40 PERCENT BUT NOT GREATER THAN 50 PERCENT OF ABOVE-GRADE WALL AREA			
ELEMENT	CONDITION/VALUE		
Skylights (U-factor)	1		
Slab or below-grade wall (R-value)	R-0		
Windows and glass doors	SHGC	U-factor	
PF < 0.25	0.4	0.7	
0.25 < PF < 0.50	0.5	0.7	
PF > 0.50	0.6	0.7	
Roof assemblies (R-value)	Insulation between framing	Continuous insulation	
	R-25	R-19	
All-wood joist/truss	R-25	R-20	
Metal joist/truss	NA	R-19	
Concrete slab or deck	R-30	R-20	
Metal purlin with thermal block	R-38	R-20	
Metal purlin without thermal block			
Floors over outdoor air or unconditioned space (R-value)	Insulation between framing	Continuous insulation	
	R-11	R-6	
All-wood joist/truss	R-11	R-6	
Metal joist/truss	NA	R-6	
Concrete slab or deck			
Above-grade walls (R-value)	No framing	Metal framing	Wood framing
Framed			
R-value cavity	NA	R-13	R-11
R-value continuous	NA	R-3	R-0
CMU, > 8 in., with integral insulation			
R-value cavity	NA, NA	R-11	R-11
R-value continuous	R-5	R-0	R-0
Other masonry walls			
R-value cavity	NA	R-11	R-11
R-value continuous	R-5	R-0	R-0

\*\*Section 805.2.1 Interior Lighting Controls; add a third sentence to read:

Large spaces shall have a separate switch or control for each 2500 square feet of floor area.

(Reason: This change is consistent with energy conservation measures in the 4th public review ASHRAE 90.1 - 1999, Space Control. This "zoning" is especially relevant for after-hours employees in office spaces.)

\*\* Chapter 9; Replace referenced standard as follows:

<del>ASHRAE/IES -- 93</del>	<del>Energy Code for Commercial and High-Rise Residential Buildings -- Based on ASHRAE/IES 90.1 1989 with Revisions thru October 7, 1997 including Errata and Addendum 90.1c-1993</del>
ASHRAE/IES -- 99	Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings -- 1999 Edition

(Reason: This adopts the most recent edition of the ASHRAE Standard 90.1 as the reference standard for commercial construction.)

END

## 10.5 Laboratory Response to Proposed NCTCOG Amendments to 2000 IECC.

December 21, 2001

Mr. John Promise  
 Director, Environmental Resources  
 North Central Texas Council of Governments  
 P.O. Box 5888  
 Arlington, TX 76005-5888

Re: NCTCOG Regional Amendments to IRC/IECC

Dear Mr. Promise:

Thank you for your letter of October 11, 2001 requesting that the NCTCOG's recommended regional amendments to the 2000 International Energy Conservation Code and to Chapter 11 of the 2000 International Residential Code be reviewed by the Energy Systems Laboratory pursuant to provisions of Senate Bill 5, 77<sup>th</sup> Texas Legislature (R.S.).

Several items in your recommended amendments will require detailed simulation before we will be able to issue a definitive determination of their impact. We have made progress toward developing a standard tool for these simulations, but anticipate that the process will take several months at least. It has been decided therefore to conditionally approve the NCTCOG amendments package with exceptions noted, and reserving judgment on the items requiring simulation. This means that, with minor modifications as noted, the proposed amendments should result in substantially equivalent energy efficiency results as the unamended codes. If it is determined on completion of our simulations that further minor modifications are needed in order to ensure that amendments do not result in less stringency, we will recommend specific limits at that time.

Items requiring simulation before a final determination of impact include:

IECC

101.3 -- The laboratory will separately review voluntary performance testing programs to determine whether they meet or exceed the IECC requirements.

302.1 -- Respecting the intent that the overall impact of standardizing the regional requirements (combining zones 5 and 6 into a single zone) be at or above results of the IECC, and recognizing that uniform standards will generally improve compliance by reducing confusion, the laboratory will review whether the impact of increased stringency for zone 5 will exceed the relaxation of the window U-factor for zone 6.

502.1.5 -- The laboratory will review the shading options to determine whether they are equivalent in impact to an average Solar Heat Gain Coefficient of .4 or less for all fenestration products.

502.2 -- The laboratory will review Table 502.2 values to determine whether the standardized values are at least equivalent in impact, overall, to the range of values in the nomographs in this section.

502.2.4 -- The laboratory will review whether the generally increased stringency of prescriptions for zone 5 will exceed limited applications of relaxed window U-factor for zone 6 (up to 12% glazing area).

IRC

N1101.2.1 -- The laboratory will review the proposed air conditioner efficiency trade-offs to determine if these will sufficiently offset the higher levels of glazing as was suggested by MECcheck.

N1102.1 -- The laboratory will review proposed Table N1102.1 to determine additional limitations that may be needed to maintain the code's stringency. For now, we recommend limiting the application of this prescriptive table to projects where the cathedral ceiling area is limited to one third or less of the total ceiling area.

We expect that after simulations have been completed, laboratory determinations on these sections will be positive or that any adjustments needed will be minor.

Exceptions taken include the following:

502.1.1 -- The exception to the requirement for a vapor barrier should be limited to your region, instead of extending to zone 9.

502.2 note g -- The recommendation of equipment inside conditioned space should include "equipment and ductwork." This is not a requirement.

Chapter 9 -- ASHRAE Standard 62-1989 has been replaced by 62-1999 (Ventilation for Acceptable Indoor Air Quality), and this reference should be updated along with 90.1.1999.

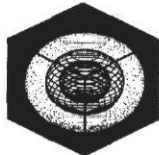
Sincerely,

Tom Fitzpatrick  
Energy/Codes Specialist

cc: Pat Baugh, Chairman-RCCC; Russ Mower, Chairman-BECAB; Kenny Calhoun, NCTCOG; Bahman Yazdani, ESL; File: SB5/IECC Amendments/NCTCOG



10.6 Laboratory Letter Regarding R-6/SEER-12 tradeoff.



**Energy Systems Laboratory**  
 Texas Engineering Experiment Station  
 Texas A&M University System  
 3581 TAMU  
 College Station, Texas 77843-3581

Date: August 28, 2002

To: Persons Interested in IRC/IECC Code Requirements for Insulated Ducts in Texas

**Subject:** Current Requirements for Residential Duct Insulation and an Alternative Implementation Approach

Effective immediately, **two (2)** options now exist for insulating ducts in attics to comply with the IRC / IECC requirements:

- 1) The building can be built to the exact insulation requirements specified in the IRC / IECC codes **OR**
- 2) The building can be constructed with reduced duct insulation and an air-conditioner with increased efficiency in the **R-6 / SEER-12 Tradeoff** method described below. The SEER-12 rating for each unit will be determined by the ARI rating for the specific equipment model numbers installed (including evaporator, condenser, and other system parts required). This tradeoff does not cover supply and return air ducts outside the building structure.

**Current IECC Code Requirements Summary:**

The current IECC code requirements for duct insulation in unconditioned attics is **R-8** for the supply duct and **R-4** for the return duct (see Table 503.3.3.3 of the 2001 Supplement to the IECC). Please refer to the attached "Detailed IRC/IECC Code Requirements" in this letter for additional information.

**Current IRC Code Requirements Summary:**

The current IRC code requirements for duct insulation in unconditioned attics is **R-5** for the supply duct and **R-5** for the return duct. Use Chapter 11 of the IRC for one- and two-family dwellings (with a glazing area that does not exceed 15% of the exterior walls) or multi-family dwellings 3 stories or less in height above grade (with a glazing area that does not exceed 25% of the exterior walls). Please refer to the attached "Detailed IRC/IECC Code Requirements" in this letter for additional information.

**Allowable Tradeoff To Use R-6 for Supply and Return Ducts Summary:**

The R-6 / SEER-12 Tradeoff allows R-6 duct insulation for supply and return ducts located in unconditioned attics when an air-conditioner with a minimum SEER-12 rating is installed to offset the energy lost by lowering the duct insulation requirements from R-8 to R-6 under the IECC requirements. The Energy Systems Laboratory has calculated the energy impact and found that this R-6 / SEER-12 Tradeoff meets the energy efficiency requirements of Senate Bill 5 of the State of Texas. This Tradeoff may be used for all one and two-family dwellings and multi-family 3 stories or less in height above grade. The SEER-12 air-conditioner may not be used to offset other lower energy efficiency substitutions when the R-6 / SEER-12 Tradeoff is used.

Please review the Detailed IRC / IECC Code Requirements attachment for further clarification.

The SB5 web page will be kept current to provide further information and updates at [//eslsb5.tamu.edu](http://eslsb5.tamu.edu).

Sincerely,

Charles H. Culp, P.E., Ph.D.  
Associate Director  
Energy Systems Laboratory  
Texas Engineering Experiment Station  
Texas A&M University System  
College Station, TX 77843-3581

1-877-AnM-CODE (toll free)

Attachment

#### **Attachment: Detailed IRC / IECC Code Requirements**

The State of Texas has adopted the Energy Efficiency requirements of the *2000 International Residential Code (IRC)* and the *2000 International Energy Conservation Code (IECC)*, as amended by the *2001 Supplement*( dated March 2001).

#### **IECC Requirements**

IECC Table 503.3.3.3, page IECC-5 of the *2001 Supplement to the International Codes* (March 2001) contains the following requirements for duct insulation:

- Ducts within unconditioned attics or outside of the building
  - Supply ducts - R-8 minimum
  - Return ducts - R-4 minimum
- Refer to the IECC Supplement for further information on unconditioned basements, crawlspaces and garages.

**Note:** For one- and two-family dwellings (with a glazing area that does not exceed 15% of the exterior walls) or multi-family dwellings 3 stories or less in height above grade (with a glazing area that does not exceed 25% of the exterior walls), one can use Chapter 11 of the IRC.

#### **IRC Requirements**

IRC Section N1103.3 Duct Insulation contains the following requirements for duct insulation:

- Supply and return ducts in unconditioned spaces within the building require at least R-5 insulation – An example of this is a duct located in an attic or a crawlspace. Note that the **R-6 / SEER-12 Tradeoff** is not required for complying with Chapter 11 of the IRC.
- Supply and return ducts located outside the building require at least R-8 insulation - An example of this is a duct located on a rooftop totally outside the building or running outside an exterior wall.
- Supply and return ducts located within the exterior wall of a building require at least R-8 insulation between the side of the duct furthest from the conditioned space and the outside of the building.

#### **Temporary Exception**

A special temporary exception to the above requirements allowed **R-6 flexible duct only**, to be used in place of R-8 flexible duct **until February 1, 2003**.

# 10.7 Texas Building Energy Code Form For Reporting Home Energy Ratings (HERs Standardized Report)

Version 1.01, September 1, 2002

Page 1 of 3

## Texas Building Energy Code Form For Reporting Home Energy Ratings (HERs Standardized Report)

Effective Date: 9/01/2002

Texas law, Ch. 388, Subtitle C, Title 5, Health and Safety Code, requires a new residential structure to comply with the Texas Building Energy Efficiency Standards, which use the 2000 International Residential Code "2000 IRC" and the 2000 International Energy Conservation Code "2000 IECC" as it existed on May 1<sup>st</sup>, 2001 (i.e., this includes the 2001 Supplement).

This standardized form can be used by Home Energy Ratings providers (HERs providers) to report the results of their energy efficiency rating for each residence rated, or results can be reported using the approved output files from accredited HERs software. This form is designed to allow HERs providers to give potential home buyers information on a structure's energy performance, including: insulation, types of windows, heating and cooling equipment, water heating equipment, building performance measurements (i.e., building tightness and duct leakage), and an overall rating of probable energy efficiency relative to the 2000 IRC Chapter #11, including the 2001 Supplement.

HERs providers who are using a RESNET accredited HERs software, can submit their results electronically using one of the approved files listed in the following table. Accredited HERs software vendors who are not listed in the table below will need to contact the Laboratory so their software reporting file can be listed.

Software	Vendor	City/State	Web Address	Phone Number	Version Number	File Type/Name
REMRate	Architectural Energy Corp.	Boulder, CO	www.archenergy.com	303-444-4149	10.3	*.mdb MS Access export file
EnergyGuage USA	Florida Solar Energy Center	Cocoa, FL	www.energyguage.com	321-638-1492	Latest version	Export file

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Version 1.01, September 1, 2002

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# **Texas Building Energy Code Form For Reporting Home Energy Ratings (HERs Standardized Report: A.1 Single Family Residential)**

Effective Date: 9/01/2002

New Construction Address or Legal Description \_\_\_\_\_  
 City \_\_\_\_\_ Zip \_\_\_\_\_ County \_\_\_\_\_  
 Date of HERs Rating \_\_\_\_\_

HERs Provider Name \_\_\_\_\_  
 HERs Provider Address \_\_\_\_\_  
 HERs Provider Phone \_\_\_\_\_  
 City \_\_\_\_\_ Zip \_\_\_\_\_ County \_\_\_\_\_  
 HERs Rating Score \_\_\_\_\_ (0 - 100)  
 Percent of 2000 IRC Chpt #11 \_\_\_\_\_ (i.e., 100% = 0% difference, 90% = 10% more efficient, etc.)

## **1. General Information**

1.1 Square footage:	_____	ft <sup>2</sup>
1.2 Building type:	_____	1) unvented crawlspace, 2) vented crawlspace, 3) slab-on-grade. (N,E,S,W)
1.3 Front of house faces	_____	Feet
1.4 Depth of house (front to back)	_____	Feet
1.5 Width of house (left to right)	_____	1, 2, or 3
1.6 Number of stories (3 max)	_____	N,E,S,W, none
1.7 Attached unconditioned garage	_____	N,E,S,W, none
1.8 Other attached unconditioned space	_____	1) ACH from blower door test at 50 Pa, or use
1.9 Building tightness	_____	2) tight, 3) medium, 4) loose.

## **2. Walls**

2.1 Front wall  
 2.2 Right wall  
 2.3 Back wall  
 2.4 Left wall

Roof Overhang (0 - 10 ft)	Total R-value	Wall Type <sup>1</sup>	Height (ft)

## **3. Windows/Doors**

3.1 Front window  
 3.2 Right window  
 3.3 Back window  
 3.4 Left window

Area (ft <sup>2</sup> )	Total U-value (0-1.2)	SHGC (0.37 - 0.9)

Area (ft <sup>2</sup> )	Total U-factor (0.35max)	SHGC(0.37-0.9) If glazed.

3.1 Front door  
 3.2 Right door  
 3.3 Back door  
 3.4 Left door

<sup>1</sup> Wall types include: 1) light weight (i.e., frame walls), 2) medium weight (i.e., veneer brick), 3) heavy weight (i.e., 8"+ masonry wall or concrete).

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## Texas Building Energy Code Form For Reporting Home Energy Ratings (HERs Standardized Report: A.1 Single Family Residential)

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**4. Floor**4.1 Floor type <sup>2</sup>

Value


1) unvented crawlspace,  
2) vented crawlspace,  
3) slab-on-grade.  
R-value  
R-value  
R-value

4.2 If slab, perimeter insulation

4.3 If crawlspace, floor insulation

4.2 If crawlspace, exterior wall insulation

**5. Attic/Roof**

5.1 Attic/Roof type

Value


1) ventilated attic,  
2) cathedral ceiling.  
0 - 1.0  
Total R-value

5.2 Solar Absorption

5.3 Attic/roof insulation

**6. Mechanical Systems**

6.1 Heating system type: 1) gas-fired furnace, 2) heat pump, 3) electric resistance heating, 4) none.

6.2 Cooling system type: 1) air-cond./heat pump, 2) evaporative, 3) none.

6.3 DHW heater type: 1) gas, 2) electric resistance, 3) heat pump,

6.4 Duct tightness: 1) CFM @ 50 Pa, 2) unknown.

**Return duct:**

6.4.1 Location

6.4.2 Insulation

6.4.3 Length

6.4.4 Location

6.4.5 Insulation

6.4.6 Length

6.5 Duct tightness:

**Supply duct:**

Value

Efficiency


HSPF or AFUE  
As appropriate  
SEER if appropriate.  
NAECA efficiency

1) attic,  
2) crawlspace,  
3) conditioned space  
R-value  
Ft

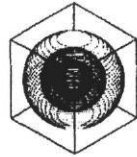
1) attic,  
2) crawlspace,  
3) conditioned space  
R-value  
Ft  
1) CFM @ 25 Pa, or  
2) unknown

<sup>2</sup> Floor types same as building type.

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10.8 Laboratory's Letter Regarding U.S.E.P.A.'s Energy Star New Homes Program.



**ENERGY SYSTEMS LABORATORY**  
Texas Engineering Experiment Station  
Texas A&M University System

3581 TAMU  
College Station, Texas 77843-3581

August 30, 2002

To All Interested Parties in SB-5 Implementation:

The Energy Systems Laboratory (ESL) has received several written and verbal requests to analyze and determine if the United States Environmental Protection Agency's (EPA) Energy Star New Homes Program can be used to achieve equivalency to the Texas Building Energy Performance Standards (TBEPS) as defined by Senate Bill 5, 77<sup>th</sup> Legislature.

The Building Option Packages (BOPS) developed by the EPA for use in Texas that are posted on the Laboratory's SB-5 Web page meet or exceed the prescriptive energy requirements of the IRC2000/IECC2000 with 2001 Supplement. It is also our determination that any residential building design that meets or exceeds the equivalent energy performance levels of the posted BOPS could be used by Texas municipal code officials as evidence of compliance with the performance requirements of the Texas Building Energy Performance Standards (TBEPS) provided that the design meets all other mandatory code requirements as defined by the local code official.

The Laboratory stands ready to analyze additional BOPS for equivalency to the TBEPS. Also, the Laboratory can assist municipal code officials, on a fee basis, to determine if other alternative design packages are TBEPS code equivalent.

The Energy Star New Homes Program and its providers offer significant energy and emissions reductions to Texas. If you or your staff have any questions, do not hesitate to contact me at 979-845-9213.

Sincerely,

*W.D. Turner*

W. Dan Turner, P.E., Ph.D.  
Director  
Energy Systems Laboratory  
Texas Engineering Experiment Station  
Texas A&M University System  
Energy Systems Laboratory Senate Bill 5 Web pages: <http://eslsb5.tamu.edu>



## 10.9 Calculations of Potential NOx Reductions

This section of the report contains the detailed calculations of the potential NOx reductions from several recommendations, including:

- Restarting the LoanSTAR and Rebuild America M&V program, combined with Continuous Commissioning<sup>SM</sup>.
- Motivating consumers to purchase SEER12 air conditioners.
- Increased use of efficient refrigerators.
- Increased use of efficient clothes washers.
- Increased use of Low-E windows.
- Increased use of solar thermal DHW systems.
- Increased use of compact fluorescents.
- Elimination of pilot lights.

These recommendations are provided so that the Senate Bill 5 policy makers will have preliminary NOx reductions estimates for a range of new policy areas that show potential for further study. Many of the values shown represent the maximum potential estimates for NOx reductions and would require substantial investments over a series of years. Therefore, detailed study is recommended for each of the measures listed before legislation is created.

### 10.9.1 Example: Potential NO<sub>x</sub> Reductions From Restarting the LoanSTAR Program M&V With Continuous Commissioning<sup>SM</sup>

In 2001 the LoanSTAR program saved Texas taxpayers \$13.1 million, which consisted of \$1.6 million in measured/stipulated heating energy savings, \$2.8 million in measured/stipulated cooling savings, \$4.0 million in measured/stipulated electricity savings, \$504,000 in measured/stipulated electric demand savings, \$3.5 million in Continuous Commissioning<sup>SM</sup> savings, and \$1.1 million in estimated savings. For cost effectiveness, LoanSTAR measures the savings for at least the first two years after the retrofit, after which the cost associated with the continuation of the meter is paid annually by the participating state agencies. Therefore, there are many facilities that have not had continuous measurements in a number of years. Several studies have shown that energy savings in large institutional and commercial buildings can degrade by 20% or more when left unattended. Therefore, it is recommended that the LoanSTAR metering be restarted and the buildings recommissioned to assure savings are kept at the previously metered levels.

Since the cooling and electricity savings are the main savings of interest for NO<sub>x</sub> reduction calculations, the following calculations consider cooling and electricity savings only.

COOLING NO <sub>x</sub> REDUCTIONS		
Total Cooling=\$/yr	\$ 4,279,721	\$ 4,279,721
Total Cooling=MMBtu	504,814	504,814
% capture= MMBtu (15 to 25%)	75,722	126,204
Tonh= divide by 12000Btu/ton	6,310,177	10,516,961
KWh/yr = 1 kW/tonh	6,310,177	10,516,961
T&D loss (kWh) = x 1.2	7,572,212	12,620,353
MWH =	7,572	12,620
lbs-NO <sub>x</sub> = MWH x 2.6 lb/MWH	19,688	32,813
tons-NO <sub>x</sub> /yr = divide 2000	10	16
tons-NO <sub>x</sub> /182day = divide by 182 days	0.05	0.09

ELECTRICITY REDUCTIONS		
Total Elec = \$/yr	\$ 6,060,718	\$ 6,060,718
Total Elec = MWh/yr	157,148	157,148
% capture (15-25%) = MWh/yr	23,572	39,287
T&D loss (MWH) = x 1.2	28,286	47,144
lbs-NO <sub>x</sub> = MWH x 2.6 lb/MWH	73,545	122,575
tons-NO <sub>x</sub> /yr = divide 2000	37	61
tons-NO <sub>x</sub> /365day = div.365 days	0.10	0.17

TOTAL REDUCTIONS	
lbs-NO <sub>x</sub> = MWH x 2.6 lb/MWH	73,545 – 122,575
tons-NO <sub>x</sub> /yr = divide 2000	46.4 – 77.7
tons-NO <sub>x</sub> /day = divide (365 or 182)	0.15 - 0.26

If one assumes that the cost for restarting the LoanSTAR program is equal to twice the annual savings (i.e., about a 2 year payback), and that the annual cost for M&V is about 10% of the savings, then the economics of the retrofit can be calculated as follows:

\$ Total annual savings	\$2,600,000
\$ Cost to restart	\$5,200,000
\$ Annual cost of M&V	\$260,000
\$/ Ton / first yr	\$69,924 - \$112,554
\$ / Ton / 10 yr	\$9,703 - \$16,250
\$ / Ton / 10 yr-day	\$26.58 - \$89.28

### 10.9.2 Example: Potential NOx Reductions From Upgrading SEER-9/10 Air Conditioner to SEER-12.

Currently, the 2000 IECC/IRC requires the use of SEER 10 air conditioner for new residential construction, which is at the Federal efficiency level of SEER 10. Fortunately, many air conditioner manufacturers now offer efficiencies considerably higher than SEER 10. If consumers could be motivated to purchase more efficient air conditioners considerable NOx reductions could result. For example, a review of recent Air Conditioning and Refrigeration Institute (ARI) reports for single-phase units (65,000 Btu/h or less) in Texas revealed that significant savings are available if customers installed SEER 12 air conditioners<sup>77</sup>. These savings would translate into significant NOx reductions as shown in Figure 53, which represent the cumulative peak day NOx reductions from air conditioner purchases for the Houston-Galveston area (HGA) during the period 1997 through 2008.

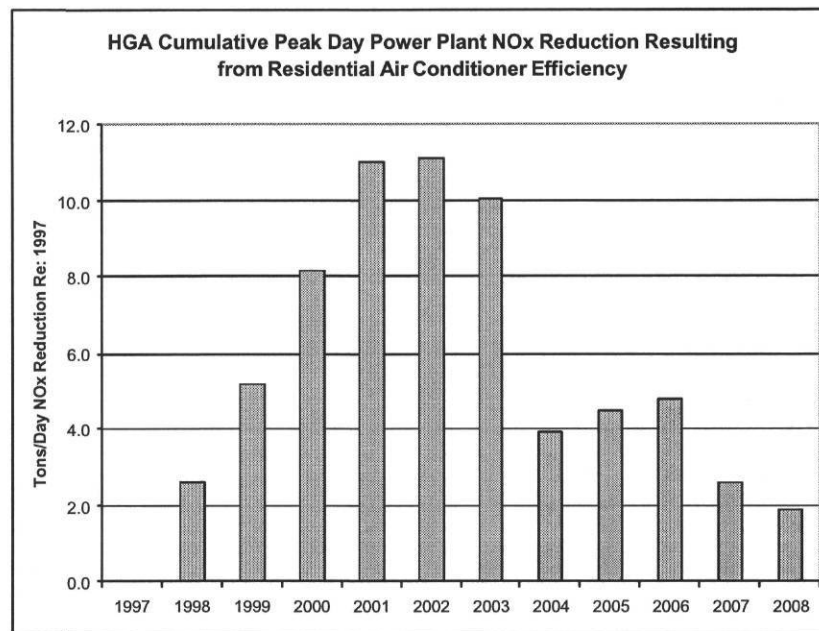


Figure 53: NOx Reductions From Increasing Efficiency of Residential Central Air Conditioners (Source: ARI 2002).

Several features are worth point out in this figure. First, Significant NOx reductions accumulate up until 2003 when the TNRCC-mandated power plant NOx reductions are scheduled to be in place at the utility power generation plants. This is cause of the 2:1 drop in NOx reductions from 2003 to 2004. Nevertheless, beginning in 2004 and continuing through 2006, NOx reductions from air-conditioner upgrades continue at about ½ the rate prior to 2002, which still make a significant contribution to NOx reductions.

Therefore, if all replacement air conditioning units could be encouraged to be SEER-12 or better, the following potential for NOx reductions can be calculated<sup>78</sup>. In this calculation a number of assumptions have been made. First, according to the ARI, 716,000 units were sold in Texas in 1999, of which 260,000 already were SEER 12, 70,000 were covered in the PUC-reported savings, leaving 386,000 unaccounted

<sup>77</sup> Unpublished ARI Internal Report by Kareem Amrane, Ph.D., Air Conditioning and Refrigeration Institute, Arlington, VA (July).

<sup>78</sup> The preliminary calculations for the SEER 9/10 to 11/12 air-conditioning upgrades presented in the July 2002 TERP report by the Laboratory have been changed to reflect comments received from the TERP Advisory Board and others. The changes include the following: a) the number of air conditioners was updated to 2003 projections, b) the T&D losses were reduced to 1.1 from 1.2, c) the lbs-NOx/MWh was changed from 2.6, the statewide average published by TNRCC for all utilities in June 2002, to 1.54, TNRCC's projected value for the statewide 2003 average, and d) the upgrade costs were reduced to \$200 and \$500 from the previous values of \$300 to \$600 for the SEER 9/10 to 9/12 and SEER 9/11 to 9/12 upgrades.

for, which are the basis for these calculations, which have been projected to the year 2003. Second, two calculations are presented to demonstrate the importance of calculating peak day NOx reductions when considering weather related energy conservation measures such as air conditioning upgrades. The first two columns calculate the tons of NOx/day for an average 1,936 ft<sup>2</sup> house, with a 5.1 ton air conditioner, using the annual MWh for the state divided by 365<sup>79</sup>, which yields an average daily NOx reduction of 0.5 to 1.1 tons NOx/day.

In the first column, the annual electricity savings are calculated for an existing SEER 9 to SEER 10 upgrade, that is now upgraded to a SEER 12 using a IECC code-traceable DOE-2 simulation<sup>80</sup>. In the second column the annual electricity savings for an existing SEER 9 to SEER 11 upgrade, that is now upgraded to a SEER 12, also using the DOE-2, IECC code-traceable simulation developed by the Laboratory. The “tons/day” shown for the first two columns represent the annual average (i.e., the total divided by 365).

In the third and fourth column the peak NOx reductions are shown as calculated by the same DOE-2 simulation. To accomplish this calculation the whole-building kWh/day for the simulated peak day<sup>81</sup> was compared, which yields a peak day daily NOx reduction of 1.6 to 3.6 tons NOx/day, which is considerably larger than the average day NOx reductions emphasizing the need for a refined analysis that uses peak day calculations, or an equivalent adjustment, versus annual average tons of NOx/day<sup>82</sup>.

CONVERT SEER 10 or 11 to 12	AVG SEER 9/10 to 9/12	AVG SEER 9/11 to 9/12	PEAK SEER 9/10 to 9/12	PEAK SEER 9/11 to 9/12
Units sold/yr 2003	756,000	756,000	756,000	756,000
Already SEER 12 or above	260,000	260,000	260,000	260,000
Covered by PUC rebate	70,000	70,000	70,000	70,000
units / yr not covered	426,000	426,000	426,000	426,000
kWh/yr (DOE2 sim) or kWh/day	1,146	529	9.84	4.54
T&D losses	1.1	1.1	1.1	1.1
MWh/yr or MWh/day	537,016	247,889	4,611	2,127
lbs / MWh	1.54	1.54	1.54	1.54
lbs / yr or lbs/day	827,004	381,750	7,101	3,276
tons / yr	414	191		
tons /day or tons/day	1.1	0.5	3.6	1.6
\$/ House additional cost	\$ 200	\$ 500	\$ 200	\$ 500
\$ Total	\$ 85,200,000	\$ 213,000,000	\$ 85,200,000	\$ 213,000,000
\$/ ton / first yr	\$ 206,045	\$ 1,115,915		
\$/ ton / 10 yr	\$ 20,604	\$ 111,591		
\$/ton/10 yr-365day	\$ 56	\$ 306		

<sup>79</sup> This is the procedure used by the U.S. EPA's EGRID database, which has been proposed by the TNRCC.

<sup>80</sup> This simulation assumes a 5.1 ton air conditioner, 1,936 ft<sup>2</sup> house in Ft. Worth, Texas, with 25% window-to-wall area, R-27 ceiling insulation, R-14 wall insulation, air-conditioner SEER as shown. The TMY2 weather file for Ft. Worth was used in the simulation.

<sup>81</sup> The peak day chosen by DOE-2 was July 29<sup>th</sup>, which is an historical average weather day, according to the TMY2 calculation procedures.

<sup>82</sup> It is this calculation that led the Laboratory to believe that the use of the EGRID program would need adjusting for the proper accounting of NOx reductions associated with the cooling season.

### 10.9.3 Example: Potential NOx Reductions From the Use of Efficient Refrigerators

Energy efficiency of residential refrigerators varies significantly from manufacturer to manufacturer, with more efficient models arriving daily at appliance stores. Unfortunately, most consumer purchases are based primarily on cost, brand name identification, and features. Energy efficiency can easily vary from 100 to more than 150 kWh/year for an average sized refrigerator using the U.S.D.O.E. Energy Guide values, and has no relationship to the cost of the refrigerator<sup>83</sup>.

Therefore, if new energy efficient refrigerators could be installed in 75% of the 8.8 million households in the state, the following potential NOx reductions can be calculated, based on the assumption that there is a \$100 cost associated with this increased energy efficiency<sup>84</sup>.

	100 kWh saved/yr	150 kWh saved/yr
kWh/yr-savings/ref=	100	150
Houses 2003=	8,830,503	8,830,503
Already installed = 25%	0.75	0.75
T&D losses=	1.1	1.1
MWh/yr savings=	728,516	1,092,775
lbNOx/yr/MWh=	1.54	1.54
lbsNOx/yr=	1,234,107	1,851,160
tons/yr=	617	926
tons/day=	1.7	2.5
\$ cost/refrigerator=	\$ 100	\$ 100
Refrigerators=	6,622,877	6,622,877
\$Total first cost=	\$ 662,287,725	\$ 662,287,725
\$ / ton / yr=	\$ 1,073,307	\$ 715,538
\$/ton/10yr=	\$ 107,331	\$ 71,554
\$/ton/10yr-day=	\$ 294	\$ 196

<sup>83</sup> Energy efficiency is related to other features, such as insulation levels, and whether or not the refrigerator has an automatic ice maker.

<sup>84</sup> The preliminary calculations for the refrigerator upgrades presented in the July 2002 TERP report by the Laboratory have been changed to reflect comments received from the TERP Advisory Board and others. The changes include the following: a) the total number of houses was adjusted to reflect the statewide population, b) T&D losses were reduced to 1.1 from 1.2, and c) The lb-NOx/MWh was reduced from 2.6 to 1.54 to reflect TNRCC's projected value for the statewide 2003 average.

#### 10.9.4 Example: Potential NO<sub>x</sub> Reductions From the Use of Efficient Clothes Washers

Unlike refrigerators, the energy efficiency of clothes washers is highly dependent on what kind of washer, with horizontal axis machines having the edge over vertical axis machines. Savings also varies significantly from manufacturer to manufacturer, with more efficient, less expensive horizontal axis models arriving daily at appliance stores. Unfortunately, most consumer purchases are based primarily on cost, brand name identification, and features. Energy efficiency can easily vary from 300 to 400 kWh/year using the U.S.D.O.E. Energy Guide values for clothes washers. Horizontal axis clothes washers also use considerably less water as well.

Therefore, if new energy efficient clothes washers could be installed in 90% of the 8.8 million households in the state, the following potential NO<sub>x</sub> reductions can be calculated, based on the assumption that there is a \$300 to \$700 cost associated with this energy efficiency improvement<sup>85</sup>.

	300 kWh/yr saved	400 kWh/yr saved
kWh/yr-savings/wash=	300	400
Washers=	8,830,503	8,830,503
Already installed = 10%	0.90	0.90
T&D losses=	1.1	1.1
MWh/yr savings=	2,622,659	3,496,879
lbNO <sub>x</sub> /MWh=	1.54	1.54
lbsNO <sub>x</sub> /yr=	4,442,785	5,923,713
tons/yr=	2,221	2,962
tons/day=	6	8
\$ cost/washer=	\$ 300	\$ 700
Washers=	7,947,453	7,947,453
\$Total first Cost =	\$2,384,235,810	\$ 5,563,216,890
\$ / ton / yr=	\$ 1,073,307	\$ 1,878,287
\$/ton/10yr=	\$ 107,331	\$ 187,829
\$/ton/10yr-day=	\$ 294	\$ 515

<sup>85</sup> The preliminary calculations for the clothes washer upgrades presented in the July 2002 TERP report by the Laboratory have been changed to reflect comments received from the TERP Advisory Board and others. The changes include the following: a) the total number of houses was adjusted to reflect the statewide population, b) T&D losses were reduced to 1.1 from 1.2, and c) The lb-NO<sub>x</sub>/MWh was reduced from 2.6 to 1.54 to reflect TNRCC's projected value for the statewide 2003 average.



### 10.9.5 Example: Potential NOx Reductions From the Use of Compact Fluorescent Lamps

New energy efficient lighting, such as compact fluorescents, also offers significant savings in energy use when compared to traditional light sources, such as incandescents. For example, a 60 Watt incandescent can now be replaced with a similar sized lamp that provides the same amount of light, and yet only uses 15 Watts of energy. Compact fluorescents also last considerably longer than incandescents, usually about 6,000 hours<sup>86</sup>. If every household in Texas could be motivated to replace 10 incandescent lamps with 10 compact fluorescents, then the following potential NOx reductions could be calculated<sup>87</sup>, assuming the average prices shown<sup>88</sup>.

	10 @ 60W to 15W	10 @ 75W to 20 W
10 lamps @ original = kW	0.060	0.075
10 CFL @ lower = kW	0.015	0.020
Life per lamp = hrs	6,000	6,000
kW difference x 10 lamps	0.45	0.55
hrs/yr = 4hrs x 365 days	1,460	1,460
kWh savings/yr-house	657	803
Elec.cost = \$0.1/kWh	\$ 0.10	\$ 0.10
\$saved @ \$.1/kWh	\$ 66	\$ 80
T&D losses	1.10	1.10
Houses in state 2003	8,830,503	8,830,503
MWh saved	6,381,805	7,799,983
lbsNOx/yr = 1.54 x MWh	9,827,979	12,011,974
TonsNOx/yr = /2000	4,914	6,006
TonsNOx/day	13.5	16.5
\$/lamp	\$ 6.50	\$ 7.50
Lamps = Houses x 10	88,305,030	88,305,030
\$Total first Cost =	\$ 573,982,695	\$ 662,287,725
\$/ton/first yr	\$ 116,806	\$ 110,271
\$/ton/10yr	\$ 55,622	\$ 52,510
\$/ton/10yr-day	\$ 152	\$ 144

<sup>86</sup> The 6,000 hour life is what is reported by one manufacturer. Values as high as 10,000 hours are used by other manufacturer.

<sup>87</sup> The preliminary calculations for the CFL lamp replacements in the July 2002 TERP report by the Laboratory have been changed to reflect comments received from the TERP Advisory Board and others. The changes include the following: a) the total number of houses was adjusted to reflect the statewide population, b) T&D losses were reduced to 1.1 from 1.2, c) The lb-NOx/MWh was reduced from 2.6 to 1.54 to reflect TNRCC's projected value for the statewide 2003 average, d) the wattage of the 60W incandescent replacement was increased to 15W, and the wattage of the 75 W replacement was increased to 20W, and e) the hours of use for each lamp were changed.

<sup>88</sup> These prices were obtained from the local Wal Mart on 6/26/2002. Prices may be lower or higher depending upon the store in which the lamps are sold and the quantity of lamps purchased.

### 10.9.6 Example: Potential NOx Reductions From the Use of Low-E Windows in Existing Houses

Clearly, the installation of Low-E windows in new construction contributes significantly to the energy reductions versus a standard house with average windows as defined by the NAHB survey data. However, if Low-E windows could be installed in 90% of the houses in Texas, then significant NOx reductions can be calculated as follows<sup>89</sup>, using an IECC/IRC-traceable DOE-2 simulation of a 2,000 to 2,500 ft<sup>2</sup> house with 18% window to floor area. The \$1/ft<sup>2</sup> cost is for added cost of using Low-E versus double-pane, clear glazing, which results in the following estimates<sup>90</sup>.

	2000 ft <sup>2</sup> house	2500ft <sup>2</sup> House
No.Houses=	8,830,503	8,830,503
ft <sup>2</sup> windows/house	2,000	2,500
% windows/floor area	0.18	0.18
ft <sup>2</sup> windows/house	360	450
Total ft <sup>2</sup> windows	3,178,981,080	3,973,726,350
Total ft <sup>2</sup> houses	17,661,006,000	22,076,257,500
Assume % that need low-E	0.90	0.90
kWh/yr-ft <sup>2</sup> =Savings/ft <sup>2</sup> (DOE-2)	1.3037	1.3037
kWh/yr-house=	2,607	3,259
Total MWh/yr x 1.1 T&D =	22,794,407	28,493,009
lbNOx/MWh=	1.54	1.54
lbNOx/yr=	35,103,386.8	43,879,233.4
Tons-NOx/yr=	17,552	21,940
Tons/cool day182	96.4	120.5
\$ Extra cost/ft <sup>2</sup> window LowE=	\$ 1.00	\$ 1.00
Total ft <sup>2</sup> windows=	3,178,981,080	3,973,726,350
\$Total Cost (lowE upgrade only) =	\$ 3,178,981,080	\$ 3,973,726,350
\$ / ton / first-yr=	\$ 181,121	\$ 181,121
\$/ton/10yr=	\$ 18,112	\$ 18,112
\$/ton/10yr-cool-day182=	\$ 99.52	\$ 99.52

<sup>89</sup> The preliminary calculations for the low-E window upgrades presented in the July 2002 TERP report by the Laboratory have been changed to reflect comments received from the TERP Advisory Board and others. The changes include the following: a) the total number of houses was adjusted to reflect the statewide population, b) T&D losses were reduced to 1.1 from 1.2, and c) The lb-NOx/MWh was reduced from 2.6 to 1.54 to reflect TNRCC's projected value for the statewide 2003 average.

<sup>90</sup> The 182-day adjustment is used here to estimate the impact of NOx emissions reductions on a peak day since the Laboratory's analysis of similar measures has shown a 2:1 difference between average 365-day EGRID values and peak values.

## 10.9.7 Example: Potential NOx Reductions From the Use of Solar DHW Systems

Renewable energy systems also offer a substantial opportunity for reducing NOx emissions in Texas. If solar thermal domestic hot water systems could be installed in 50% of the 8.8 million houses in the state, then the following potential NOx reductions can be calculated<sup>91</sup>. The cost of these systems is estimated for two systems: a system with two 4 ft x 8 ft panels and an 80 gallon storage tank, and a system with one 4 ft x 8 ft panel with a 40 gallon rooftop storage tank. The delivery of these systems is estimated to be 80 and 50% respectively<sup>92</sup>.

	\$4800 2x4x8,w/80 gal	\$3000 1x4x8,w/40 gal
No.People/house=	4	3
Gal/person/day = 20	80	50
Btu/day = galx8.34x (75-140)	43,368	27,105
MMBtu/yr = x 365/1e6	15.8	9.9
MMBtu/yr= w/N.G.eff = .75	21.1	13.2
Solar Fraction =	0.80	0.50
No.Houses=	8,830,503	8,830,503
Penetration= 50%	0.50	0.50
Total MMBtu/solar=	74,549,791	29,121,012
lbsNOx/yr=MMBTu x .25 =	18,637,447.70	7,280,253.01
Tons/yr	9,318.72	3,640.13
Tons/day	25.53	9.97
\$ cost/system=	\$ 4,800	\$ 3,000
Systems=	4,415,252	4,415,252
\$Total first Cost =	\$ 21,193,207,200	\$ 13,245,754,500
\$ / ton / first-yr=	\$ 2,274,261	\$ 3,638,817
\$/ton/10yr=	\$ 227,426	\$ 363,882
\$/ton/10yr-day=	\$ 623	\$ 997

<sup>91</sup> The preliminary calculations for the solar system installations presented in the July 2002 TERP report by the Laboratory have been changed to reflect comments received from the TERP Advisory Board and others. The changes include the following: a) the total number of houses was adjusted to reflect the statewide population.

<sup>92</sup> This 50 to 80% efficiency refers to the ability of the system to provide the total annual domestic water heating needs. Usually, these systems provide all the needs in the summer months, falling short of the needs in the winter months as the systems strain to provide heating during periods of lower incident solar radiation, and falling ambient temperatures.

### 10.9.8 Example: Potential NOx Reductions From Elimination of Pilot Lights

A large number of houses in the non-attainment and affected counties have active pilot lights that burn throughout the year. Pilots lights are used on all natural gas appliances to ignite the main burner when there is a demand for heating, water heating, etc. Although the new TNRCC rule 117 limits the amount of NOx that can be produced by certain types of gas consuming appliances it does not specifically address pilot lights<sup>93</sup>.

Fortunately, in new furnaces, manufacturers have decided to replace pilot lights with hot surface ignition devices that ignite the gas with a surface heated to the ignition point using electricity. This has been added to home furnaces to meet the higher furnace efficiencies. Unfortunately, only a few manufacturers of natural gas fired domestic water heaters offer hot surface ignition.

Therefore, there are millions of pilot lights in Texas that could be replaced with hot surface igniters. The potential NOx reduction can be calculated as follows<sup>94</sup>, based on the assumption that houses have, on average 0.85 to 1.35 pilot lights<sup>95</sup>:

	85% with Pilot Lights	135% with Pilot Lights
# homes 2002=	8,830,503	8,830,503
Btu/h per pilot light=	500	500
Percent DHW w/p.light=	0.50	0.75
Percent FURN w/p.light=	0.35	0.60
total pilots/house=	0.85	1.35
hrs/yr burning=	8,760	8,760
MMBtu/yr=	32,875,963	52,214,764
lbNOx/MMBtu-NG=	0.25	0.25
LbNOx / yr=	8,218,991	13,053,691
TonNOx / Yr=	4,109	6,527
TonNOx / Day=	11.3	17.9

<sup>93</sup> A telephone survey of water heater manufacturers revealed that most of the manufacturers were unaware of TNRCC's Rule 117 and the July 1<sup>st</sup>, 2002 implementation date. None of the manufacturers could say how they were going to comply with this ruling and/or if this required the elimination of the pilot light. Many of the manufacturers already have units in stock that can meet the low-NOx requirements of TNRCC's Rule 117, however many distributors do not have sufficient stock of the low-NOx units.

<sup>94</sup> The preliminary calculations for the pilot light replacements presented in the July 2002 TERP report by the Laboratory have been changed to reflect comments received from the TERP Advisory Board and others. The changes include the following: a) the total number of houses was adjusted to reflect the statewide population, b) the number of pilot lights per house have been changed, and c) the cost per house has been changed.

<sup>95</sup> The lb-NOx values used were 0.25 lb-NOx/MMBtu from Ottinger 1991, and assume an open flame NOx emission value..

If one assumes that the average cost for such an upgrade is \$170 – 270/house (i.e., this assumes that the upgrade is performed at the time that the device is normally replaced) then the economics of the retrofit can be calculated as follows:

\$ / House to fix=	\$ 170	\$ 270
\$/ MMBtu average cost=	\$ 5	\$ 5
\$ / Yr savings per house=	\$ 19	\$ 30
\$ total cost=	\$ 750,592,755	\$ 1,788,176,858
\$/ Ton / first yr=	\$ 182,648	\$ 273,973
\$ / Ton / 10 yr=	\$ 18,265	\$ 27,397
\$ / Ton / 10yr-day=	\$ 50	\$ 75

## 10.10 Calculations of Potential NO<sub>x</sub> Reductions From Implementation of IECC/IRC

### 10.10.1 Overview

The procedures used to calculate the electricity savings from implementation of the IECC/IRC were previously outlined in this report in Section 5 of this report. First, new construction activity by county had to be determined, then energy savings attributable to the IECC/IRC had to be modeled using the DOE-2 simulation program, next, estimates of the NO<sub>x</sub> reduction potential from the electricity reductions in each county were calculated using the average lb-NO<sub>x</sub>/MWh published by TNRCC<sup>96</sup>.

The preliminary findings are shown in

Table 4. For each county two simulations were performed using the appropriate weather file as indicated for the IECC climate zone. The annual electricity savings/household, and peak day savings were then multiplied by the number of building permits to estimate the countywide savings for the projected houses to be built in 2002<sup>97</sup>. Next an assumption was made about the Transmission and Distribution losses (T&D losses = 20%) to yield the total MWh savings per county. Then, the TNRCC lb-NO<sub>x</sub>/MWh factors<sup>98</sup> for the appropriate utility service district were applied<sup>99</sup> to allow for the estimation of the potential NO<sub>x</sub> reductions from the calculated IECC/IRC reductions. As indicated, these lb-NO<sub>x</sub>/MWh can vary significantly from Reliant's 1.88 to TXU's 3.34 lb-NO<sub>x</sub>/MWh.

### 10.10.2 Simulation of Electricity Savings With Code-traceable DOE-2 File.

The estimated savings from implementation of the IECC/IRC to the non-attainment and affected counties were calculated by simulating the annual energy use of an average 1999 household as defined by the NAHB survey data. These values are listed below for each climate zone and the counties that it served. The NAHB survey data also lists the average house size according to "east" or "west" location, also as indicated.

The IECC/IRC-traceable code simulation uses a square house of either 2,548 or 2,426 ft<sup>2</sup>, with equal wall areas on all four sides (8 ft wall height). Latitudes and longitudes were adjusted to match each county. The weather file used is as indicated in

Table 4. Window areas are calculated as a window-to-wall ratio as indicated. The windows are also equally distributed on all four sides, and do not include any shading effects. The slab-on-grade house has one zone (11.5 lb/ft<sup>2</sup>), and includes an unconditioned 2-car garage attached to the north side of the house. The building has two exterior doors, as defined by the IECC/IRC. Roof and wall absorptance, emittance and roughness were constant for all runs. Window U-values and SHGC values were calculated using NFRC 100 and 200 guidelines assuming multiple 3.0 (w) by 5.0 (h) windows with aluminum frames (w/o thermal break). All houses had an SEER 11 air-conditioner<sup>100</sup>, and an 80% AFUE natural gas-fired furnace, as required by the IECC/IRC. Duct losses were kept constant for all runs. The 1999 houses were assumed to have pilot lights in the furnace and DHW. In the IECC/IRC houses pilot lights were eliminated on the furnaces<sup>101</sup>. Furnace and air-conditioner size is as calculated by DOE-2<sup>102</sup> using 1 CFM/FT<sup>2</sup> air

<sup>96</sup> This preliminary analysis does not include power transfers on the grid, and assumes transmission and distribution losses of 20%. Counties were assigned to utility service districts as indicated in Table 4.

<sup>97</sup> These projections were developed using linear averages of the published permits for each county.

<sup>98</sup> The lbs-NO<sub>x</sub>/MWh are those published in the TNRCC's June 5, 2002, Houston/Galveston Attainment Demonstration and Post-1999 Rate-of-Progress SIP, Appendix A: Description of the Methodology for Determining Credit for Energy Efficiency, Table 3.

<sup>99</sup> The application of the average TNRCC lb-NO<sub>x</sub>/MWh does not take into account the grid interaction between utility providers, which assumes all power was provided by each utility in their service area. A more accurate analysis, would take into account the grid-related power exchanges.

<sup>100</sup> The choice of a SEER 11 efficiency for the air conditioner was based on ARI sales numbers for Texas which show an average SEER 11 for houses built in 1999.

<sup>101</sup> This assumption is based on conversations with several furnace manufacturers who related the fact that all new NG furnaces have hot surface ignitors to meet the higher federal AFUE requirements.

<sup>102</sup> DOE-2.1e version 119 was used for the calculations. The HVAC system used was the RESYS2 system.

distribution. Night-setback thermostats were used, as required by the IECC/IRC. Infiltration rates were assigned as 0.57 ACH, as required by the IECC/IRC<sup>103</sup>. Each building has a fixed 3,000 Btu/h internal load, also as required by the IECC/IRC.

In Table 5 through Table 8 the variables are listed for the 1999 average house and the IECC 2001 house. For each climate zone the counties are listed that are contained in that climate zone, as prescribed by the IECC/IRC. The "Area %" represents the percent of window to wall area for an average house. The 1999 glazing U-value, SHGC, roof and wall U-values represent the NAHB averages. The IECC/IRC values shown are as listed for the climate zone and % window area combination.

### Climate Zone 3

Nueces	East
San Patricio	East
Victoria	East
Brazoria	East
Galveston	East

	1999 East	IECC 2001	1999 West	IECC 2001
Area %	15	15	23.7	25
Floor Area	2548	2548	2426	2426
Glazing U value	1.11	0.75	0.87	0.55
SHGC	0.77	0.4	0.73	0.4
Roof Insulation	27.08	R-19	26.75	R-30
Wall Insulation	13.99	R-11	14.18	R-13
AFUE	80	80	80	80
SEER	11	11	11	11

Table 5: Zone 3 input assumptions for DOE-2 simulations.

<sup>103</sup> The IECC/IRC references ASHRAE Standard 136, which includes a weather factor for various cities in Texas, which varies from 0.76 to 1.14. For this preliminary analysis a weather factor of 1.0 was used.



Climate Zone 4

Bastrop	East	Harris	East
Bexar	East	Jefferson	East
Caldwell	East	Liberty	East
Comal	East	Montgomery	East
Guadalupe	East	Orange	East
Wilson	East	Tarrant	West
Chambers	East	Waller	East
Fort Bend	East	Hardin	East

	1999 East	IECC 2001	1999 West	IECC 2001
Area %	15	15	23.7	25
Floor Area	2548	2548	2426	2426
Glazing U value	1.11	0.75	0.87	0.52
SHGC	0.77	0.4	0.73	0.4
Roof Insulation	27.08	R-26	26.75	R-30
Wall Insulation	13.99	R-13	14.18	R-13
AFUE	80	80	80	80
SEER	11	11	11	11

Table 6: Zone 4 input assumptions for DOE-2 simulations.

Climate Zone 5

Ellis	West
Hays	West
Johnson	West
Rusk	East
Smith	East
Travis	West
Williamson	West
Collin	West
Dallas	West

	1999 East	IECC 2001	1999 West	IECC 2001
Area %	15	15	23.7	25
Floor Area	2548	2548	2426	2426
Glazing U value	1.11	0.65	0.87	0.5
SHGC	0.77	0.4	0.73	0.4
Roof Insulation	27.08	R-30	26.75	R-38
Wall Insulation	13.99	R-13	14.18	R-13
AFUE	80	80	80	80
SEER	11	11	11	11

Table 7: Zone 5 input assumptions for DOE-2 simulations.

Climate Zone 6

Gregg	East	Rockwall	West
Harrison	East	Upshur	East
Kaufman	West	Denton	West
Parker	West	El Paso	West

	1999 East	IECC 2001	1999 West	IECC 2001
Area %	15	15	23.7	25
Floor Area	2548	2548	2426	2426
Glazing U value	1.11	0.6	0.87	0.46
SHGC	0.77	0.4	0.73	0.4
Roof Insulation	27.08	R-30	26.75	R-38
Wall Insulation	13.99	R-13	14.18	R-16
AFUE	80	80	80	80
SEER	11	11	11	11

Table 8: Zone 6 input assumptions for DOE-2 simulations.

Using the code-traceable DOE-2 simulations on the 91,632 new houses projected for 2002, the following estimates for potential NO<sub>x</sub> reductions can be made. The 2,426 – 2,548 ft<sup>2</sup> refers to the average house size according to the NAHB for east and west Texas. The 297,160 MWh/yr savings is from Table 4. A +/- 20% adjustment has been added to the DOE-2 simulations to give a range of savings. The “tons/peak-cool-day” are the kWh consumed by the average IECC/IRC house as simulated by the DOE-2 program. The \$500 cost estimate is based on discussions with local builders and code officials<sup>104</sup>.

	DOE-2 (-20%)	DOE-2 (+20%)
Size of House	2,548	2,426
No.Houses=	91,632	91,632
Total MWh/yr =	297,160	297,160
lbNO <sub>x</sub> /MWh=	Average/service dist.	Average/service dist.
Tons-NO <sub>x</sub> /yr = (417 +/-20%)	333.6	500.4
Tons/365day = (1.14 +/-20%)	0.912	1.368
Tons/peak-cool-day = (2.09 +/-20%)	1.672	2.508
\$ Extra cost for IECC/IRC/house	\$ 500	\$ 500
Total Cost	\$ 45,816,000	\$ 45,816,000
\$ / ton / first-yr=	\$ 137,338	\$ 91,559
\$/ton/10yr=	\$ 13,734	\$ 9,156
\$/ton/10yr-day =	\$ 37.63	\$ 25.08
\$/ton/10yr-peak-day =	\$ 20.52	\$ 13.68

Table 9: Calculation of potential NO<sub>x</sub> reductions from implementation of IECC/IRC.<sup>104</sup> Local code officials in the Bryan/College Station area.